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THE PEGMATITE MINERALS FROM NEAR AMELIA, VIRGINIA*

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1. INTRODUCTION

The first commercial mica mines near Amelia Court House, Virginia, were opened in the early seventies, and the remarkable size and quality of the mica early awakened a keen economic interest in the pegmatite dikes of the region, but the richness of the locality in rare and beautiful mineral specimens has promoted a scientific interest which has persisted for sixty years. Thirty-six mineral species have been reported from the Rutherford mine alone, and the variety and perfection of many of these have led to their inclusion in most of the museums of the world. The concentration of unusual minerals in an easily accessible deposit attracted various scientific investigators and mineral collectors to this locality for successive generations. Such intensive investigation of a locality might suggest that little remains to be learned about its minerals, but the recent opening of a new mine near Amelia and the reopening of the Rutherford mine have given new

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opportunities for study. Moreover, most of the minerals from Amelia were described before the development of modern methods for the study of minerals.

In May 1932, a group of geologists from the United States Geological Survey visited the Amelia region. The fresh dump from recent mining operations at the old Rutherford mine, which was at that time being operated for its output of gem-quality amazonstone, furnished a new supply of most of the rare and interesting minerals for which the locality is famous. Although the specimens collected do not contain examples of all the minerals reported from the Rutherford mine, a representative group of minerals, whose optical properties have not previously been determined, were selected for microscopic and spectrographic study. The opening of a new deposit, referred to as the Morefield mine, a few years previous, disclosed a similar set of minerals with the added occurrence of zinnwaldite, triplite, unaltered and well formed phenacite crystals, and large crystals of topaz.

The following mineralogical descriptions refer chiefly to the less common minerals—notably microlite, phenacite, topaz, and zinnwaldite. Several varieties of sericite are described, with analyses, and notes on nearly all the minerals, with new optical determinations, are added.

This paper is essentially descriptive of the minerals of the Amelia pegmatites and so mineral relations have been only touched upon and paragenesis has not been considered. However, it is recognized that these problems are of fundamental interest and it is planned to follow the present paper by another, in which the mineral sequence as shown by the individual mineral relations will be described, and the paragenesis, thus indicated, discussed.

The writer wishes to acknowledge the courtesy of Mr. Ezell Keener and of Mr. S. V. Morefield, whose permission to collect much of the material here described, has made this paper possible. She also wishes to express her appreciation to the following chemists of the United States Geological Survey for the several analyses, the determinations of the alkalies in several minerals, and for the spectrographic examinations. The complete analyses were made by J. J. Fahey, J. G. Fairchild, and R. E. Stevens; the alkali determinations by R. E. Stevens and R. C. Wells; and the spectrographic examinations by George Steiger. In addition, she wishes to thank C. S. Ross and W. T. Schaller, of the United States Geo-

logical Survey, for their helpful criticisms and advice during the preparation of this paper.

2. RUTHERFORD MINE

The earliest working of the mica deposits of what is known as the Rutherford mine is thought to have been done by Indians. Early settlers observed evidence of excavation and the removal of mica from the upper 10 feet of the vein, but it was not until 1873 that the deposit was opened for commercial mining.

The first report on the minerals of this area was made by Fontaine¹ in 1883. Since that time more than 40 papers have been published on the subject. These papers deal primarily with the descriptive mineralogy, the chemical analyses, and economic importance of the individual minerals. Detailed descriptions of the Virginia pegmatite mines and minerals are contained in the works of T. L. Watson,² D. B. Sterrett,³ and E. S. Bastin.⁴ The most recent publication on this region and one in which the geology and petrology of the pegmatites have been discussed was written by A. A. Pegau.⁵

The Rutherford mine is developed on two large parallel dikes $1\frac{1}{4}$ miles northwest of Amelia Court House and half a mile west of the Richmond-Danville Railroad.

The two openings are about 100 yards apart. The one to the northeast, recently reopened, is on a gently sloping hillside and consists of an L-shaped excavation 165 feet deep, opening through a 100-foot vertical shaft. The other opening is at the foot of the hill, where the deepest workings are reported to have reached a depth of 150 feet. These workings were abandoned in 1912, and at the present time there is a small pond about 50 feet wide and 100 feet long that marks the site of the old mine.

¹ Fontaine, W. M., Notes on the occurrence of certain minerals in Amelia County, Virginia: *Am. Jour. Sci.*, 3d ser., vol. 25, pp. 330-339, 1883.

² Watson, T. L., Mineral resources of Virginia: *Virginia-Jamestown Exposition Commission*, pp. 275-285, 385-392, 1907; Annual report on the mineral production of Virginia during the year 1908: *Virginia Geol. Survey, Bull.* 1A, pp. 101-106, 1909.

³ Sterrett, D. B., Gems and precious stones: *U. S. Geol. Survey, Mineral Resources* 1912, pt. 2, pp. 1045-1048, 1913; Mica deposits of the United States: *U. S. Geol. Survey, Bull.* 740, pp. 20-23, 307-330, 1923.

⁴ Bastin, E. S., Quartz and feldspar: *U. S. Geol. Survey, Mineral Resources* 1910, pt. 2, pp. 971-973, 1911.

⁵ Pegau, A. A., Pegmatite deposits of Virginia: *Virginia Geol. Survey, Bull.* 33, 1932.

3. MOREFIELD MINE

The Morefield mine is $1\frac{1}{2}$ miles southeast of Winterham, and about $4\frac{1}{2}$ miles east of Amelia Court House. The elevation is about 300 feet and the surface slopes eastward toward the Appomattox River. The geological features of the region are shown on the Geologic Map of Virginia.⁶ The mine is in a nearly vertical parallel-sided pegmatite, about 15 feet wide, which strikes southwest, and is reported to outcrop continuously along the surface for about 1,500 feet. The adjacent country rock like that at the Rutherford mine⁷ is described by Pegau as a pre-Cambrian porphyritic biotite gneiss, which was originally a biotite-quartz monzonite. In the region of the Morefield mine these rocks are intruded also by numerous narrow diabase dikes, which are distinctly later in age than the pegmatites.

The Morefield mine was opened by Mr. S. V. Morefield in 1929, and was operated first by the Seaboard Feldspar Company of Baltimore, Md., and later intermittently by Mr. Morefield. The workings in June 1933 consisted of an open cut 10 or 15 feet deep following the dike for a distance of 200 feet, and a shaft which had been sunk to about 40 feet. More extensive work was resumed by Mr. Morefield in 1934.

The minerals of the Morefield dike show a symmetrical zonal arrangement, with an irregular middle zone of smoky gray quartz, intergrown on its borders with large crystals of beryl and topaz. The blue-green microcline (amazonstone) borders the quartz zone on both sides; albite and muscovite with occasional crystals of garnet form an irregular zone on the wall side of the amazonstone. The narrow, fine-grained selvage bands composed of biotite and quartz occupy the contact between the coarse-grained pegmatite mass and the country rock, and are probably reaction zones with the country rock.

The texture of the dike is coarse-grained with unusually large well formed crystals, particularly of topaz, zinnwaldite, amazonstone, and beryl. The deposit differs mineralogically from the Rutherford pegmatite bodies chiefly in the presence of a considerable quantity of phenacite and in the abundance of large crystals of topaz and of zinnwaldite. The largest known crystal of zinnwaldite was obtained from this deposit.

⁶ Geologic map of Virginia, *Virginia Geological Survey*, 1928.

⁷ Pegau, A. A., *op. cit.*

4. MINERALS

A total of 31 mineral species have been identified from the pegmatites of Amelia. Of these, eight—bertrandite, biotite, chalcopryrite, phenacite, pyrolusite, topaz, triplite, and zinnwaldite—are here described in detail for the first time. In addition 12 unconfirmed species have been reported in the literature.

The well established species from the Rutherford and Morefield mines are as follows:

TABLE 1

WELL ESTABLISHED SPECIES FROM THE RUTHERFORD (R) AND THE MOREFIELD (M)
MINES, NEAR AMELIA, VIRGINIA

(The species marked with a star (*) are established by the writer.)

Mineral	Mine		Remarks	First reference ^a
	R	M		
Albite	R	M	.....	Fontaine, W. F.
Allanite	R	—	Described by Fontaine under the name Orthite.	Fontaine, W. F.
Almandite	R	—	Almandite-spessartite.	Pegau, A. A.
Apatite	R	—	.....	Rowan, G. H.
*Bertrandite	R	—	.....
Beryl	R	M	.....	Fontaine, W. F.
*Biotite	—	M	.....
Calcite	R	—	.....	Pegau, A. A.
Cassiterite	R	M	.....	Gordon, S. G.
*Cerussite	R	—	.....
*Chalcopryrite	R	—	.....
Columbite	R	M	Described by Lee and Wherry as manganotantalite	Fontaine, W. F.
Fergusonite	R	—	.....	Fontaine, W. F.
Fluorite	R	M	.....	Fontaine, W. F.
Galena	R	M	.....	Fontaine, W. F.
Helvite	R	—	.....	Fontaine, W. F.
Manganotantalite	R	M	Same as Fontaine's columbite.	Lee, O. I., and Wherry, E. T.
Microcline	R	M	.....	Fontaine, W. F.
Microlite	R	M	.....	Fontaine, W. F.
Monazite	R	M	.....	Fontaine, W. F.
Muscovite	R	M	.....	Fontaine, W. F.
Phenacite	R	M	.....	Yeates, W. S.
Pyrite	R	—	.....	Fontaine, W. F.

^a See selected bibliography at end of paper.

TABLE 1 (Continued)

Mineral	Mine		Remarks	First reference
	R	M		
*Pyrolusite	—	M	Fontaine, W. F. Fontaine, W. F. Yeates, W. S. Pegau, A. A.
Quartz	R	M	.....
Spessartite	R	M	.....
Topaz	R	M	.....
Tourmaline	R	M	.....
*Triplite	—	M	.....
*Zinnwaldite	—	M	Watson, T. L.
Zircon	R	M	.....

TABLE 2

UNCONFIRMED SPECIES FROM RUTHERFORD (R) AND MOREFIELD (M) MINES,
NEAR AMELIA, VIRGINIA

Mineral	Mine		Remarks	Reference
	R	M		
Andradite (topazolite)	R	—	Probably helvite.	Pegau, A. A.
Anglesite	R	—	Mentioned by early writers but not described.	Pegau, A. A.
Cyrtolite	R	—	Probably zircon. No description.	Gordon, S. G.
Hatchettolite	R	—	Reported but not described.	Gordon, S. G.
Ilmenite	R	—	Specimen said to have been obtained at Rutherford mine was presented to Watson.	Watson, T. L.
Lepidolite	R	—	Pegau reported this later to be pink muscovite.	Peagu, A. A.
Leverrierite	R	—	Reported but not described. Possibly sericite.	Gordon, S. G.
Labradorite	R	—	Now known to be chatoyant albite.	Fontaine, W. F.
Oligoclase	R	—	Now known to be chatoyant albite.	Watson, T. L.
Orthoclase	R	—	Probably microcline. Fontaine described it as light green in color.	Fontaine, W. F.
Pyrochlore	R	—	Reported by G. W. Fiss. No description given.	Fontaine, W. F.
Stibnite	R	—	Reported by G. W. Fiss. No description given.	Fontaine, W. F.

A brief description is given of the minerals collected by the writer in 1932 and 1934. The optical determinations are grouped in two tables, one for the micas and the other for the remaining minerals, placed at the end of the mineralogical description. No extended descriptions of the more common minerals of these pegmatites, ordinary microcline, muscovite, and quartz, are given.

Albite.—Two distinct varieties of albite are prominent at the Rutherford mine. The most abundant is the well known cleavelandite variety, in distinct platy crystals which were common in both the older and the newer workings. The new dump is largely composed of such specimens. The angular cavities between the network of interlocking platy crystals contain the rarer minerals. Chemical determinations made by Mr. Stevens of the alkalis of this cleavelandite showed: $K_2O = 0.33$ per cent, $(Na, Li)_2O = 11.65$ per cent, Rb_2O none, Cs_2O none.

The second variety of albite is in large masses, of a pearl-gray tint and exhibits delicate blue chatoyancy on the cleavage faces. Called labradorite by Fontaine, and oligoclase and oligoclase-albite by others, optical determinations show it to be about 94 per cent albite. This chatoyant albite, in distinction from the cleavelandite variety, is not in distinct crystals and is not the host of many of the rarer minerals. Only the olive-colored microlite and the olive-buff colored muscovite have been found in it.

Strikingly different from both types of albite in the Rutherford mine are two varieties at the Morefield mine, where small white to transparent glassy crystals about 1 centimeter in length form a granular mass intermingled with mica and garnet in the outer feldspar zone, and a more fragile and splintery Nile-blue variety which encloses small crystals of olive-colored microlite.

Bertrandite.—The rare hydrous beryllium silicate, bertrandite, has been found only at the Rutherford mine. It forms small prismatic colorless crystals about 1 mm. in length implanted on the walls of cavities in the deeply etched honey-colored variety of beryl, and in cavities in albite.

Beryl.—The early literature reported pale bluish-green and dingy yellow crystals of large size, some 3 or 4 feet in length and as much as 18 inches in diameter, from the Rutherford mine. Only small groups of tiny yellow crystals in cavities of albite were seen in the new workings of this mine. Some of the beryl crystals found at the Morefield mine are equal in size to those formerly reported from

the Rutherford mine. So far, most of the beryl found at the Morefield mine is opaque, with a color range from white to pale bluish-green (lichen green).⁸ The crystals are euhedral and are intergrown with the amazonstone and quartz. Some show muscovite crystals projecting at right angles from the prism faces, or hexagonal cup-like imprints where muscovite crystals have been removed. The alkalies present in the beryl were found by Mr. Stevens to be: $K_2O=0.12$ per cent, $(Na,Li)_2O=0.54$ per cent, Rb_2O none, $Cs_2O=0.08$ per cent.

Biotite.—The contact between the pegmatite body and the wall rock in the Rutherford mine is sharp. In the Morefield mine, however, a conspicuous contact zone is developed. The wall between the coarse pegmatite mineral zone and the country rock is lined with a fine-grained felt-like layer of biotite 8 to 11 inches thick.

The biotite occurs mostly in scale-like plates 3 to 5 mm. across, loosely matted together, but slightly oriented so as to give the mass a suggestion of schistosity. Fine-grained quartz is the most common interstitial mineral. Small nodules and crystals of spessartite are interspersed through the mass. Microscopic crystals of apatite and zircon are also present.

The biotite is splendid black and in its physical properties closely resembles lepidomelane. Chemical determinations, however, by J. J. Fahey show that this is an iron rich biotite, having 26.72 per cent FeO , 2.87 per cent Fe_2O_3 , and 3.60 per cent TiO_2 .

Calcite.—Calcite is rare but several masses 2 cm. long were collected from the fresh dump of the Rutherford mine. The color ranges from opaque ivory yellow to transparent pale amber. It forms wedge-shaped or triangular masses in the interspaces of the cleavelandite albite. Some of the ivory colored calcite forms thin detached plates, loosely arranged like tiny cards in a file, occupying the box-like cavities in the cleavelandite. The plates are parallel to the base $c\{0001\}$ and give a perfectly centered uniaxial optical figure. This habit represents the high temperature form.⁹ Calcite has not been found in the Morefield mine up to the present time.

Cassiterite.—Cassiterite from the new dump at the Rutherford mine is glossy pitch-black with adamantine luster. It is massive, in angular pieces 1 to 4 cm. long, and is embedded in the cleave-

⁸ Ridgway, Robert, Color Standards and Nomenclature, used throughout.

⁹ Schaller, W. T., The crystal cavities of the New Jersey zeolite region: *U. S. Geol. Survey, Bull.* 832, p. 47, 1932.

landite albite. At the Morefield mine, the cassiterite has a dull gray submetallic luster, and is found in irregular fragments about 3 cm. long, scattered sparsely through the disintegrating albite in the zone of weathering.

Cerussite.—The lead carbonate forms a thin crust of dark grayish black crystals on the surface of the galena masses. The crystals are about 1 mm. in diameter and are pyramidal in form with prominent $p\{111\}$ faces.

Chalcopyrite.—Chalcopyrite forms flattened crystals or scale-like plates on the walls of the interspaces in the cleavelandite albite. It sometimes occupies portions of cavities partly filled with the platy calcite, and occurs also in the cavities partially filled with sericite.

Fluorite.—One of the most remarkable varieties of fluorite known is the chlorophane associated with microlite and other rare minerals in the pegmatite dikes at Amelia, Va., where it occurs at both the Rutherford and Morefield mines. Most of the material is extremely fractured, so that it readily crumbles when touched. This fragile variety is pale fluorite green in color. Early observers noticed the unusually strong fluorescence exhibited by this fluorite while subjected to heat just below redness. In addition to the fluorescence, a brilliant light green phosphorescence is obtained when the mineral is exposed to ultra-violet radiation.

After exposure to sunlight, these chlorophane specimens produce dense images on a photographic plate similar to those produced by radioactive substances. This photographic effect is not obtained, however, on repeating the experiment with a sheet of black paper interposed between the specimen and the plate, but the effect is marked when a piece of colorless glass is interposed. After the specimens had been kept in darkness for several hours they did not produce photographic images. The radiation phenomenon appears to be due to some solarization effect.

The same specimens were tested in a gold-leaf electroscope. The specimens that had been exposed to sunlight showed a remarkably strong activity response (.093), but after they had been kept in darkness for 24 hours no activity response could be observed.

At the Morefield mine fluorite is present in two forms; one, the chlorophane variety described above; and another, a colorless variety, in flattened octahedrons embedded in sheets of muscovite (Fig. 1).

Galena.—Galena has been found only at the Rutherford mine, some of the masses weighing 500 grams. The galena has been deposited in the interstices between the plates of albite. A crust composed of cerussite crystals forms a coating on the surface of some of the galena.

Manganotantalite, also called columbite, a tantalate of manganese and iron, is abundant in both mines. Crystalline masses 12 cm. thick, 10 cm. across, and 13 cm. long were reported from the old Rutherford mine where the mineral from the upper portion of the deposit is black and that from the lower levels is dark red with a higher specific gravity. The manganotantalite obtained from the



FIG. 1. Flattened octahedra of fluorite in muscovite. $\frac{2}{3}$ natural size. Morefield mine, near Amelia, Virginia.

fresh dump at the Rutherford mine is deep reddish-brown in thin splinters and has an adamantine luster. It occupies interstices in the cleavelandite albite and is completely unaltered by weathering.

Manganotantalite occurs in well developed crystals at the Morefield mine in association with amazonstone and quartz near a zone of topaz and beryl. Some of the crystals are 5 cm. in length and show a distinct tabular or rectangular prism form. Heart-shaped contact twins are abundant. More than 100 pounds of this mineral was mined from a single pocket of the dike near the surface. The brightness of the crystal faces is remarkably well preserved in view of the fact that the mineral occurs in the weathered portion of the dike. The color in hand specimen is black with a purple iridescence but in thin section the mineral is golden brown, nearly opaque.

Microcline.—Green microcline (amazonstone) is present in abundance in the Amelia pegmatites and is one of the most conspicuous minerals in the mines. The color ranges from light turquoise-green to sulphate-green. The green microcline forms cleavage masses which are commonly marred by fractures and seldom show crystal form, although several large well-formed crystals have been found. In the zone of oxidation leaching solutions have followed the fractures and destroyed the green color of the mineral near the crevices, leaving a white ground mottled with patches of green. From the deeper part of the mines, however, the mineral is of gem quality in both color and texture.

The amazonstone obtained from the recent operation of the Rutherford mine shows a minimum of the common perthitic character and has a uniform deep blue-green color. The cleavage is so perfect that pieces of the mineral may easily be split into very thin plates. This variety exhibits marked pleochroism from colorless to deep green in millimeter thick sections.

Spectrographic analysis of this deeper colored variety of amazonstone was made by George Steiger, who found in addition to the usual constituents, lithium, rubidium, lead, and probably a trace of tin.

The following percentages of the alkalis were found by R. E. Stevens on separated portions of the green and white microcline which formed sharp contact in the same cleavage piece.

	<i>Green microcline</i>	<i>White microcline</i>
K ₂ O	14.38	15.44
(Na, Li) ₂ O	1.54	0.92
Rb ₂ O	1.02	0.42
Cs ₂ O	trace	0.10

Microlite.—The rare mineral, microlite, essentially a calcium tantalate containing accessory columbium, fluorine, uranium, and rare elements, was especially abundant in the early workings of the Rutherford mines. Well formed octahedral crystals up to 5 cm. in diameter have been collected, and crystalline masses, some of which weighed 8 pounds, were described by Fontaine.¹⁰ Perfect octahedra 2 to 3 cm. in diameter could be obtained from the dump of the new workings, although anhedral masses were small and rare.

Microlite in the Rutherford mine is of two distinct types. One

¹⁰ Fontaine, W. M., *op. cit.*

is translucent and varies in color from dark olive-buff to dark olive; this type occurs as well formed single octahedral crystals having highly polished surfaces. The other type is transparent and varies in color from a reddish-yellow to dark amber, and resembles closely some types of garnet and of monazite. It occurs occasionally in imperfect, complex, isometric forms, but more commonly in irregular crystalline masses. The density of this variety is 6, and that of the olive-colored variety is 5.5 to 5.7; the amber variety is also harder and more brittle than the olive-colored variety. The indices of refraction also are slightly different. The mode of occurrence and the association of the two types are somewhat different. The octahedra of the olive-colored variety are embedded in the grayish chatoyant albite in close association with an olive-buff muscovite; the amber variety, apparently of a younger generation, occurs in spaces between plates of the cleavelandite albite.

Observations made by the electroscope showed that the olive-colored variety gave a marked radioactive response, whereas the amber-colored variety showed only an exceedingly feeble response, if any.

X-ray patterns of the two varieties show that the olive and amber colored microlites agree in structure. The olive-colored variety exhibits so much absorption of the x -rays that one must assume that heavy elements have entered the microlite lattice.

A comparison of the physical and optical properties of the two varieties is given in table 3.

TABLE 3
COMPARISON OF PHYSICAL AND OPTICAL PROPERTIES OF THE TWO VARIETIES OF
MICROLITE FOUND AT THE RUTHERFORD MINE

	<i>Olive-colored microlite</i>	<i>Dark amber-colored microlite</i>
COLOR	Olive-buff to dark olive.	Reddish-yellow to amber brown (resembles monazite).
CRYSTAL SYSTEM AND HABIT	Isometric. Perfect octahedral. Occurs in individual crystals, faceted and undistorted.	Isometric. Modified octahedral. Faceted crystals rare. Forms distorted. Occurs mostly as fractured crystalline masses.
FRACTURE AND CLEAVAGE	Conchoidal, compact (not brittle). Cleavage lacking or nearly so, probably parting.	Uneven fracture, seldom conchoidal. Brittle. Cleavage good, distinct.

TABLE 3 (Continued)

LUSTER	Waxy, opaque, some fragments translucent. Submetallic on crystal faces.	Vitreous to resinous, transparent.
HARDNESS	Can be scratched by the amber-brown microlite. Scratches apatite. H=about 5.5.	Harder than the olive microlite. Scratches orthoclase, can be scratched by quartz. H=about 6.
SPECIFIC GRAVITY	5.49 to 5.74	5.9 to 6.0
INCLUSIONS	Microlite crystals inclose cavities in center filled with small albite crystals.	None
ASSOCIATION	In chatoyant-albite in close association with pale olive-buff muscovite.	In cavities of the white reticulated cleavelandite type of albite.
RADIOACTIVITY	Strong (electroscope test).	Weak, hardly perceptible. (electroscope test)
INDEX OF REFRACTION	$n = 1.93$ to 1.94 .	$n = 1.98$ to 2.02 .

At the Morefield mine microlite occurs more sparingly. The largest octahedrons observed are about $1\frac{1}{2}$ cm. in diameter, are dark olive in color, and are found most commonly in a Nile-blue variety of very fragile, crumbly albite. A sample of this microlite, when crushed to a coarse powder and then placed on a glass plate and exposed on an Eastman process photographic plate for 7 days, gave a faint but distinct image. The same sample placed directly on the photographic plate for the same length of time gave a dense black image. The optical properties of this microlite are identical with those of the olive-colored variety from the Rutherford mine.

A pale honey-colored variety of microlite is also present at the Morefield mine, but it occurs in very small granular masses and as tiny flattened crystals in the white albite. This form of microlite closely resembles helvite in appearance and has a refractive index of 2.00.

Monazite.—Until recently the only locality in Virginia where monazite has been reported was the Rutherford mines. Here large coarse crystalline masses, or aggregates of crystals, some of which equaled the largest microlite masses in weight (8 pounds) were

found in the early workings. At first the monazite was not recognized as such because the specimens so closely resembled microlite. The slight visible difference was assumed to be due to surface alteration of the microlite; the real difference was discovered by chemical analysis. Some of the early literature describes monazite under the name of microlite. Fontaine¹¹ calls attention to this error. It is evident that the physical appearance of the two minerals is confusing where crystal faces are missing. No specimens of monazite were available from the new dump at the Rutherford mine, but a specimen which had been obtained from the same mine several years ago and labeled "monazite" was examined by the writer. It was found to be optically isotropic, $n=2.00$, and had a specific gravity of 6.

Monazite occurs sparingly at the Morefield mine. The crystals have an amber color, but are well formed and easily distinguished crystallographically from the microlite, which they resemble in color. So far as has been observed at the Morefield mine, the monazite occurs as single flattened crystals which penetrate or partially enclose manganotantalite crystals of about the same size. This interlocked association with manganotantalite is a conspicuous characteristic of the monazite.

Muscovite.—The pale amber transparent variety of muscovite, which for a long time was the important economic mineral of the Amelia pegmatite deposits, has been described repeatedly by other writers. In the new workings of the Rutherford mine, an olive-buff colored muscovite commonly associated with the olive-colored microlite in the chatoyant albite, is shown by spectrum analysis to contain beryllium, tin, and boron; and a shell-pink variety, which occurs in tiny fan-shaped plates in the cavities of cleavelandite, is found to contain germanium.

A sericitic variety of muscovite, sometimes designated as "damourite," although abundant at the Rutherford mine, has received little or no attention. This type of muscovite is characterized by compact fibrous to scaly structure, a silky luster, and a talc-like feel. It is closely associated with microcline and albite, and contains fragmental inclusions of topaz, of which it probably is an alteration product. Although called hydrous micas, these minerals do not appear by chemical analyses to contain any more water than ordinary muscovite.

¹¹ Fontaine, W. M., *op. cit.*

Five varieties of sericite were studied and their physical and optical properties and mode of occurrence are recorded in table 5. The composition of these sericitic muscovites is shown in table 4, the last column of which also gives the analysis of the zinnwaldite to be described later.

Some of the rarer elements contained in these muscovites but not recorded in the chemical analyses are shown in the table of spectrographic analyses (Table 7).

Variety 1 of sericite is water-green in color and is composed of irregular aggregates of micaceous plates of microscopic size. These aggregates have a roughly schistose or fibrous habit and split into splintery tabular plates parallel to schistosity, and are terminated by smooth planes inclined at about 60° to the elongation. Many of the cleavage plates show a wavy, terrace-like structure. This green variety is penetrated by veinlets of the lilac-colored variety with cleancut contacts. The minerals most closely associated with these sericitic muscovites are albite and a few fragments of topaz about 5 mm. long.

Variety 2 is maize yellow, and its aggregates split into tabular plates terminated by smooth planes varying from 60° to 75° to the elongation. The minerals associated with this variety of muscovite are topaz and albite, the topaz crystals 5 mm. long being enclosed in a matrix of the muscovite.

The purple sericitic muscovites (varieties 3 and 4) vary in color from aniline lilac to grayish lavender. They occur in two forms—tiny scales or granules closely fitted together, and in compact, waxy, talc-like masses which, under high magnification, appear to be aggregates of minute scales or fibers, a little more rounded than those in variety 5, although somewhat sericitic. Varieties 3 and 4 are optically identical. These varieties of muscovite are found intimately associated with the bluish colored cleavelandite albite, in some places filling interstices between the albite plates.

Variety 5 is an opaque massive type of sericite, consisting of aggregates of microscopic crystals, some platy but mostly fibrous, arranged in diverse positions. It ranges in color from marguerite yellow to chalcedony yellow, and bears a striking similarity to massive talc in its greasy feel and silky luster. This variety occurs in greater abundance than the others of this group and is associated with the microlite-bearing chatoyant albite. It contains a higher percentage of iron and manganese than do the others as is shown in table 4.

TABLE 4

ANALYSES OF SERICITE (RUTHERFORD MINE) AND OF ZINNWALDITE (MOREFIELD MINE) FROM AMELIA, VIRGINIA

	1 Sericite Water green	2 Sericite Maize yellow	3 Sericite Aniline lilac	4 Sericite Grayish lavender	5 Sericite Chalcedony yellow	6 Zinn- waldite Bronze
SiO ₂	48.06	47.22	46.81	46.80	49.16	43.70
Al ₂ O ₃	32.14	32.00	36.09	35.84	30.81	22.96
Fe ₂ O ₃	} 1.12 ^a	} 1.20 ^a	} 0.25 ^a	} 0.24 ^a	none	0.59
FeO					1.43	11.67
TiO ₂	n.d.	n.d.	0.01	0.01	0.04	0.32
MgO	1.39	1.25	0.62	0.56	2.22	0.03
CaO	Trace	Trace	0.29	0.29	0.15	0.02
Na ₂ O	0.17	none	0.68	0.60	0.48	0.74
K ₂ O	9.21	8.89	10.24	10.08	10.90	9.58
H ₂ O—	2.06	3.14	0.42	0.64	0.15	0.08
H ₂ O+	5.46	5.65	5.00	5.05	4.73	1.35
P ₂ O ₅	Trace	0.12	n.d.	n.d.	n.d.	n.d.
MnO	0.20	0.14	n.d.	n.d.	n.d.	1.95
F	none	none	n.d.	n.d.	n.d.	5.52
Li ₂ O	none	none	n.d.	n.d.	n.d.	1.92
BeO	none	Present	none	n.d.	n.d.	n.d.
Rb ₂ O	n.d.	n.d.	n.d.	n.d.	n.d.	1.04
Cs ₂ O	n.d.	n.d.	n.d.	n.d.	n.d.	0.10
Less O	99.81	99.60	100.41	100.11	100.07	101.58
						2.32
						99.26

^a Iron determined as Fe₂O₃ and recalculated to FeO.

1 and 2, J. G. Fairchild, analyst; 3, 4, and 5, R. E. Stevens, analyst; and 6, J. J. Fahey, analyst. Determination of caesium by R. E. Stevens, remaining alkalis by R. C. Wells.

Phenacite.—Phenacite was found at the Rutherford mine only once by W. S. Yeates in 1890, and reported as “phenacite crystals cracked and not good specimens.” At the Morefield mine the mineral is fresh and clean, both massive and in distinct crystals. The largest piece of massive material collected by the writer is 10 cm. long and 5 cm. wide. A few transparent rhombic crystals varying from 2 to 5 cm. in diameter were collected by Mr. Morefield and submitted to this laboratory for identification. These crystals were studied by J. H. Pough of Harvard University, who found that

they were a "little unusual in that the form $d \{01\bar{1}2\}$ is poorly developed, where usually it is one of the dominant forms."¹²

The massive phenacite is intergrown with beryl, quartz, zinnwaldite, and green microcline. The phenacite so closely resembles the topaz that frequently it cannot be distinguished therefrom except by gravity separation or by microscopic examination.

Pyrite.—Sulphides are very rare among the Amelia pegmatite minerals, and pyrite is the most widespread though its total quantity is small. Scales and minute crystals are occasionally found in the cleavage cracks of the green microcline, and clusters of small cubical crystals were seen along the fracture faces and in the spaces between crystals of zircon and on the sericite at the Rutherford mine. No pyrite has as yet been found in the Morefield mine.

Pyrolusite.—Pyrolusite was noted only at the Morefield mine. In the zone of oxidation the weathering of the spessartite garnet has left a concentration of the manganese in the form of black earthy or soot-like masses of pyrolusite, completely enclosing the nodules of garnet, and as cementing material in the spaces between the granular garnet fragments. Much of the albite in the garnet zone is covered with a dense film of pyrolusite which, due to its metallic luster, resembles graphite. Dendritic coatings of pyrolusite are frequently observed on the surfaces of albite and amazonstone.

Quartz.—Quartz of several varieties has been reported from the Rutherford mine, but with the exception of a few small crystals on the walls of cavities in the cleavelandite, the common massive glassy variety is the only kind found on the dumps at present. Quartz at the Morefield mine is almost entirely the common glassy pegmatite variety. Only a few rounded crystals of smoky quartz have been found.

Spessartite.—Spessartite, the manganese garnet, was abundant in the early workings of the Rutherford mine. It was described by Fontaine as occurring in poorly formed crystals which are penetrated with a multitude of fissures so that the mineral readily shatters to pieces. This form, he said, has a hyacinth-red to brownish red color, and is embedded in the ordinary feldspar of the vein. He also described another form of spessartite as having a flesh-red to brownish purple color and occurring as granular masses intimately mixed with helvite.

Spessartite of a brownish red color, found in the platy albite and

¹² Personal communication.

similar in form to the first one described above, was plentiful on the new dumps of the Rutherford mine. This form of spessartite has an index of refraction of 1.795 and a specific gravity of 4.21.

A deep wine-red garnet found in small individual crystals 2 mm. in diameter, embedded in the olive-buff muscovite, has a refractive index of 1.805 and corresponds to spessartite.

At the Morefield mine the spessartite is found in the mica-albite zone near the outer edge of the pegmatite body and in the contact zone, as described under biotite. This spessartite forms imperfect crystals or loosely aggregated nodular masses coated on the outside by pyrolusite and resembles black walnuts in external appearance. After the manganese oxide coating is removed by acid treatment the spessartite has a flesh-red color and a refractive index of 1.804. The spessartite-almandite associated with the biotite has a deep red color and a refractive index of 1.810.

Topaz.—At the Rutherford mine topaz ranks among the scarcest of the minerals, occurring only in centimeter thick fragments scattered through the sericitic muscovite. At the Morefield mine, however, topaz is abundant and in crystals of unusual size. Some of the irregular crystal masses weighed 200 pounds; one crystal with a single termination weighed 125 pounds; three with double terminations, apparently hemimorphic, weighed 20, 25 and 28 pounds respectively. Mr. Morefield reported one large crystal which measured 44 inches in length and weighed 500 pounds. Some of the topaz is colorless and transparent, and some white and nearly opaque. The transparent glassy variety is full of fractures and shatters easily. The white massive type is dense and contains numerous bubble inclusions. The topaz crystals are associated with the green microcline, quartz, and beryl. Small topaz crystals are frequently found penetrating the cleavage plates of zinnwaldite.

A quantitative determination of the alkalis by R. E. Stevens, showed that the Morefield topaz contains 0.10 per cent K_2O and 0.37 per cent $(Na, Li)_2O$. Spectrographic analysis shows that this variety of topaz also contains germanium, beryllium, and tin.

Tourmaline.—Black tourmaline occurs rarely in small aggregates of prismatic radiating crystals, usually associated with albite, beryl and quartz at the Rutherford mine. Nest-like clusters of tourmaline needles and crystals as large as a pencil, flattened and striated, have been found frequently in the Morefield mine. In

thin section the Rutherford tourmaline is brown-black and the Morefield is blue-black.

Triplite.—Triplite is here reported for the first time from the Amelia locality. It is found in crystalline masses at the Morefield mine. The specimens collected exhibit cores of unaltered translucent salmon-colored triplite masses measuring about 2 cm. in diameter surrounded by zones of brownish-black triplite showing adamantine luster. The triplite is embedded in a matrix of albite and quartz, both stained black with manganese oxide. Other associated minerals are green microcline and topaz.

Zinnwaldite.—The iron lithium mica zinnwaldite (a rare member of the mica group), is present in considerable quantity at the Morefield mine. This is the first occurrence of zinnwaldite reported from the Amelia locality. In the upper portion of the mine the zinnwaldite was found only in small crystals and cleavage plates varying from 1 centimeter to 5 centimeters across. The mineral is best described as having a dark rum brown color with a bronzy luster, and for convenience is referred to as bronze colored. This zinnwaldite is closely associated with topaz and albite. The bronze colored plates are frequently penetrated by crystals of topaz and other plates are interlaminated with small crystals of topaz and albite. A small quantity of another variety of zinnwaldite forms short prismatic crystals about 1 centimeter across, silvery-gray in color, embedded in phenacite and beryl, and infrequently in topaz and quartz.

Recent workings at a lower level in the mine, about 20 feet from the surface, have yielded zinnwaldite crystals of remarkable size. One dark bronze colored specimen collected from the dump, showing probably one-half or two-thirds of the original crystal, measures 19 centimeters along the a -axis, 21 centimeters along the b -axis and 11 centimeters along the c -axis, and weighs 11 kilograms (24 pounds). So far as is known this is the largest zinnwaldite crystal ever recorded. It is shown in Figure 2, reduced to $\frac{1}{3}$ natural size. The incomplete crystal is bounded by $c(001)$ cleavage, and the gliding plane $\rho(\bar{2}05)$. Other smaller pieces show faces of the gliding plane $\zeta(135)$. The axial plane is parallel to $b(010)$ and hence normal to the intersection edge of $c(001)$ and $\rho(\bar{2}05)$.

A complete analysis of zinnwaldite was made by chemists in the laboratory of the United States Geological Survey on a care-

fully selected sample of zinnwaldite from the upper level of the mine where the zinnwaldite was associated with topaz. The results of this analysis are given in the last column (No. 6) of table 4.

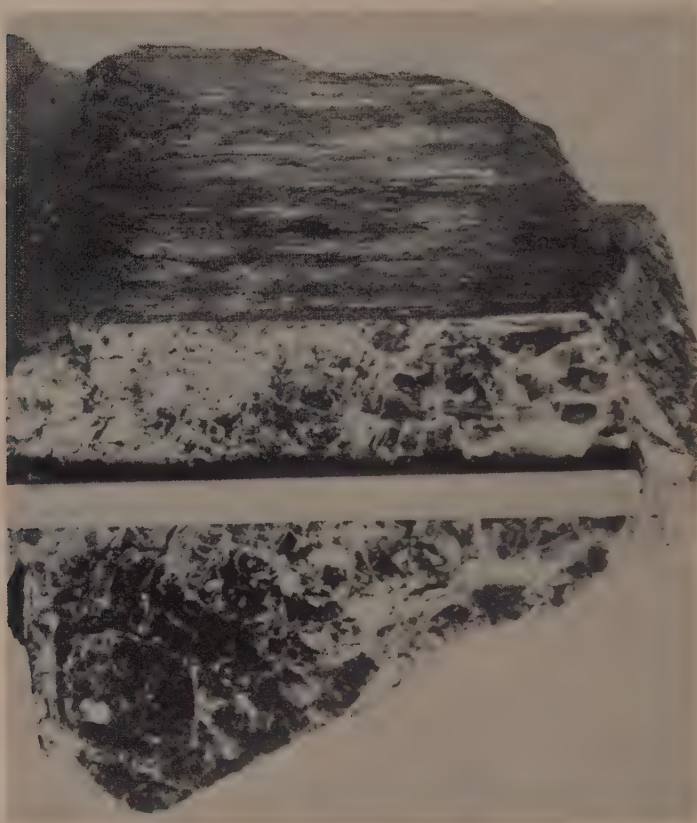


FIG. 2. Largest recorded crystal of zinnwaldite, measuring nearly a foot (21 cm. along the *b*-axis, in horizontal position) wide. The ruled face at the top is the gliding plane $\rho(205)$. $\frac{1}{3}$ nat. size. Morefield mine, near Amelia, Virginia.

Associated minerals are green microcline, gray quartz, Nile-green albite, and black manganotantalite.

Zircon.—Zircon is rare and has been found only in a few small patches in the albite in the Rutherford mine, where clusters of slender elongated radiating crystals occupy narrow wedge-shaped cavities between the interlacing crystals of the cleavelandite albite. In the Morefield mine zircon occurs as minute specks in the quartz

TABLE 5

PROPERTIES AND OCCURRENCES OF THE MICAS FROM AMELIA, VIRGINIA, AS DETERMINED BY THE WRITER

Mineral name	Mine	Color	Indices			Sign 2V dispersion	Crystallization and structure	Distinctive characters	Occurrence
			α	β	γ				
Biotite	M	Black	1.588	1.645	1.645	(-) 2V = 0°-8°	Disseminated and cleavable scales.	Resembles lepidomelane.	Along the wall contact.
Muscovite	M, R	Pale amber	1.553	1.583	1.589	(-) 2V = 47°	Hexagonal plates.	Perfect cleavage. Transparent. Colorless in thin plates.	Occurs as blocks or books along contact of feldspar and quartz.
Muscovite	R	Shell pink	1.552	1.583	1.590	(-) 2V = 45°	Small fan-shaped plates.	Satiny luster.	Occurs in cavities in cleavelandite.
Muscovite	R	Olive-buff	1.562	1.590	1.595	(-) 2V = 42°	Small hexagonal crystals.	Perfect cleavage. Vitreous luster.	Associated with microlite and chatoyant albite.
Muscovite (Sericite)	R	Water-green	1.543	1.560	1.575	(-) 2V = 70°-80° Ext. parallel	Fibrous, splits into splintery cleavage plates, terminated by 60° angle. Wavy terrace-like structure.	H = 2.5 Translucent. Luster waxy to silky. Pleochroism distinct. Y and Z colorless, X dark brown.	Associated with albite and carries inclusions of topaz. Green variety is penetrated by veinlets of purple mica.
Muscovite (Sericite)	R	Maize yellow	1.545	1.564	1.574	(-) 2V = 70°-75° Ext. parallel	Fibrous to tabular. Plates terminated planes 60° to 75° to the elongation.	Luster waxy. Translucent. Talc-like feel.	Associated with albite and fragments of topaz.
Muscovite (Sericite)	R	Anilins lilac to lavender	1.553	1.582	1.588	(-) 2V = 30°-40° variable	Varies from tiny scales, almost granular to compact.	Cleavage micaceous. H = 2. Luster pearly to waxy. Greasy, talc-like feel. Translucent to transparent.	Associated with bluish cleavelandite albite.
Muscovite (Sericite)	R	Chalcedony yellow	1.548	1.579	1.585	(-) 2V = 0°-3°	Compact aggregate of scaly and fibrous arranged in diverse positions.	Opaque in hand specimen. Resembles massive talc. Silky luster. Greasy feel	Occurs in great abundance. Associated with the microlite-bearing chatoyant albite.
Zinnwaldite	M	Rum brown or bronze to gray	1.550-1.558	1.580-1.589	1.580-1.590	(-) 2V = 0°-33° variable	Coarse bronze colored crystals and tabular cleavage plates. Gray short prismatic crystals, hexagonal.	Perfect cleavage. Bronzy to pearly or silvery luster. Fuses to black magnetic bead. Gives lithium flame.	Bronze variety associated with topaz and albite; gray variety associated with phenacite and beryl.

TABLE 6

PROPERTIES AND OCCURRENCES OF THE MINERALS, EXCEPT MICAS, FROM AMELIA, VIRGINIA, AS DETERMINED BY THE WRITER

Name of mineral	Mine	Color	Indices of refraction				Sign 2V dispersion	Crystallization and structure	Distinctive characters	Occurrence
			α	β	γ	ω				
Albite	R	Bluish pearl-gray	1.529	1.533	1.539		+ 2V = 79°	Cleavage masses.	Ab. 94. Shows delicate blue chatoyancy.	Associated with olive-colored microcline and light olive-buff (greenish) muscovite. Host for rare minerals.
Albite	R	Pale Nile-blue to white	1.528	1.531	1.538		+ 2V = 78°	Reticulated plates.	Ab. 96.	
Bertrandite	R	Colorless	1.589	1.602	1.613		2V = 78° $r < v$	Orthorhombic, prismatic. Distinct terminations.	Tiny columnar crystals in aggregates. Cleavage (110) perfect.	On cavity walls in etched beryl with quartz and albite crystals.
Beryl	M	Lichen green	1.572		1.578		-	Large hexagonal prisms.	Opaque, subtranslucent.	Intergrown with green microcline and quartz.
Beryl (Golden)	R	Honey yellow	1.568		1.575		-	Crystalline lumps. Deeply etched surfaces.	Transparent, vitreous.	In cavities of albite.
Calcite	R	Ivory to amber	1.488		1.660		Abn. small 2V	Small wedge-shaped plates.	Opaque to transparent.	In interstices in cleavelandite albite.
Cassiterite	R, M	Brownish-gray to jet black	2.09		2.00		Abn. biaxial 2V = 20° +	Irregular compact masses.	G = 6.86. Fresh surfaces glossy black. Transparent in thin section. Poly. Tw.	In interstices in cleavelandite albite.
Cerussite	R	Gray to gray-black	1.803	2.075	2.077		- 2V = 5°-10° $r > v$	Orthorhombic, pyramidal.	Adamantine luster. Transparent.	On galena masses.
Columbite (see manganoantinite)										
Fluorite	M	White		1.433				Tabular crystals.	Flattened octahedra, some resembling rhombohedral crystals.	Enclosed in muscovite crystals.

TABLE 6 (Continued)

Fluorite (Chlorophane) Manganotantalite	R, M	Fluorite green	1.434	+ 2V large	Brittle shattered masses.	Strongly luminescent.	In cavities in microcline and albite. Interstices in cleavelandite.
Microlite	R, M	Olive	1.94 ± .002		Orthorhombic. Rectangular prisms. Heart-shaped twins.	G = 7.296. Nearly opaque. Streak brown. Submetallic luster. Iridescent, non-magnetic. Reacts for manganese.	In gray chatoyant albite
Microlite	R, M	Dark amber	2.02 ± .002		Isometric. Octahedral crystal.	H = 5.5. G = 5.49-5.78. Waxy luster. Translucent.	In cavities in reticulated cleavelandite.
Microcline (amazonstone)	R, M	Green	1.516	1.523	Irregular masses. Occasionally crystal face of some isometric form.	H = 6. G = 5.9-5.0. Vitreous to resinous luster.	
Monazite	R, M	Reddish amber	1.785	1.837	Cleavage pieces. Crystals rare.	Pleochroism strong. X pale green, Y deep green, Z colorless.	Forms parallel zones or bands in main pegmatite body. Associated with quartz, beryl, topaz, etc.
Phenacite	M	White or colorless	1.671	1.655	Monoclinic. Flat tabular crystals, terminations wedge-shaped, prism faces elongated.	H = 5. G = 5.2. Luster resinous. Resembles amber colored microlite.	Associated with albite. Often enclosing crystals of manganotantalite.
Pyrolusite	M	Black			Massive. Few transparent rhombohedral crystals.	Cleavage distinct. H = 7.5. Crystals small, 5 mm. long.	Associated with beryl, quartz, and green microcline. Coating on surface of altered spessartite.
Spessartite	R, M	Salmon to red	1.795-1.810	+	Non-crystalline.	Crystals very rare.	Associated with albite, muscovite, and biotite.
Topaz	M	White or colorless	1.615	1.624	Granular nodules, crystalline masses, and rounded grain-like dodecahedrons.	H = 8. G = 3.60. Doubly terminated crystals 12 to 14 inches long.	Associated with beryl, quartz, green microcline, and zinnwaldite.
Tourmaline	R, M	Jet black	1.637	1.667	Crystalline masses and apparently hemimorphic orthorhombic crystals.	Pleochroism strong. ω = brown, ϵ = yellow.	Associated with quartz, topaz and green microcline.
Triplite	M	Salmon	1.660	1.679	Hexagonal. Prismatic radiating masses.	Resembles spessartite. Resinous to adamantine luster.	Associated with albite, quartz, and green microcline.
Zircon	R, M	Wood brown	1.98	2V near 90° +	Crystalline masses. Elongated prisms.	Radiating slender crystals and square prisms.	In cavities of cleavelandite. Pyrite crystals occur in joint cracks in zircon crystals.

and microcline, and as well formed square prisms in the albite. One of the largest crystals seen by the writer was a square prism $2\frac{1}{2}$ cm. long.

The properties and occurrences of the minerals studied are summarized in tables 5 and 6. Only those determinations made by the writer are included.

5. RARER ELEMENTS IDENTIFIED BY SPECTROGRAPHIC ANALYSES

Spectrum analysis is being widely adopted in mineralogical laboratories as an accessory means of identification of mineral species and for the determination of the presence of rare elements in their composition.

Analyses by this method were made by Mr. George Steiger on 28 specimens from Amelia, Va. Mr. Steiger tested each specimen for only eight elements—copper, lead, bismuth, tin, zinc, germanium, beryllium, and boron. These particular metals were selected because they give distinct spectral lines and tests could be made by placing finely ground material directly in the arc, without preliminary concentration by chemical treatment. The tests are accurate to .02 or .03 per cent, probably larger for copper.

The graphite electrode contains sufficient copper to give two persistent lines, and unless other copper lines were visible copper was not reported as present.

Tests were made, after concentration, on three specimens for lithium, rubidium, and caesium. Two samples of amazonstone, one from each mine, and the zinnwaldite from the Morefield mine, show lithium and rubidium. Any caesium lines that may have been present were obscured by other interfering lines.

Twelve of the samples contained boron. Without an exception all the micas contained boron, and this element is also present in the chatoyant albite and in the phenacite.

A wide distribution of beryllium is indicated by the fact that nearly half of the samples tested showed its presence.

Copper occurs "doubtful" in beryl and in spessartite.

Germanium is a characteristic constituent of topaz. In a compilation of spectrum analyses by Fitch¹³ of London, topaz from 38 localities in different parts of the world contained germanium. Fifteen samples of topaz from various localities, including a sample from Morefield mine, have been examined by Mr. Steiger and all

¹³ Fitch, A. A., *Spectrum analysis in mineralogy*, London, Adam Hilger, Ltd.

were found to contain germanium. The shell pink muscovite from the Rutherford mine, however, is the only mica which contains germanium. Spessartite from both mines contains germanium.

Lead appears in all of the feldspars, fluorite, manganotantalite, and the shell pink muscovite.

Tin is the most widely distributed metal of this group; it occurs in 17 out of 28 specimens. Tin is present in all the micas but one.

The lithium content of the Amelia minerals as a whole is remarkably low for pegmatites of this type. Except in zinnwaldite, so far as has been observed, lithium occurs only in the amazonstone and the beryl.

TABLE 7

RARER ELEMENTS IN MINERALS FROM AMELIA, VIRGINIA, IDENTIFIED BY SPECTRUM ANALYSES

(R=Rutherford mine; M=Morefield mine)

x=present; t=trace; d=doubtful.

Name of mineral	Mine	Bi	B	Be	Cu	Ge	Pb	Sn	Zn
Albite (chatoyant)	R		x				x	x	
Albite (white)	R						d	x	
Beryl	R			x					
Beryl	M			x	d				
Cassiterite	R							x	d
Fluorite	M, R			x			x	x	
Manganotantalite	R						x	x	
Manganotantalite	M			d				x	d
Microcline (white)	M						x		
Microcline (green)	M, R						x		
*Microlite	R			x				x	
Muscovite (amber)	M, R		x						t
Muscovite (pink)	R		x			x	x	x	
Muscovite (olive)	R		x					x	
Phenacite	M		x	x					
Sericite (lilac)	R		x					x	
Sericite (green)	R		x	x				x	
Sericite (yellow)	R		x	x				x	
Sericite (buff)	R		x					x	
Spessartite	R					x			
Spessartite	M				d	x		x	
Topaz	M, R			x		x		x	
Tourmaline	R		x	x					
Zinnwaldite	M		t	x				x	t

* Crowded lines in the spectrum obscured everything except Be and Sn.

Rubidium is present in the zinnwaldite and in the green microcline.

A trace of zinc appeared in the amber muscovite and in the zinnwaldite.

6. LUMINESCENCE OF MINERALS FROM AMELIA, VA.

A description of the "phosphorescence" of the chlorophane type of fluorite from the Rutherford mine is contained in the early literature on the Amelia County minerals, but luminescent properties of other minerals in that locality have not been recorded.

While making confirmatory tests of previous observations on chlorophane, a group of other minerals from the same locality were examined for reaction to heat and to ultra-violet radiation.

Chlorophane, which exhibits very unusual luminescent phenomena, has been described under fluorite.

The opaque white variety of topaz was found to be remarkably thermoluminescent. When powdered fragments of the mineral were sprinkled on an iron plate heated to just below redness the grains gave off a bright, steady glow of pure white light. The glassy transparent variety, however, glows only feebly.

The chatoyant albite shows an active response to heat and also to friction produced by rubbing (triboluminescence), the light given off in both cases being bluish-white.

The fragile somewhat altered albite, which occurs associated with the manganese garnet (spessartite) at the Morefield mine, responds readily to heat and gives off a white luminous glow. Calcite from the Rutherford mine exhibits a spectacular and colorful luminescent effect when heated. The glow is an intense flame color grading into deep orange, which persists for a much longer period than the white glow of the silicates. Other minerals which exhibit thermoluminescence, although briefly and feebly, are cleavelandite, phenacite, and microlite.

Under ultra-violet light (mercury vapor lamp) the chlorophane glows with a vivid green fluorescence with persists for some time after the mineral has been removed from the source of radiation. Calcite gives off a brilliant crimson fluorescence, but does not show an afterglow. Zircon glows with a soft golden yellow light which dies away when the mineral is removed from the ultra-violet rays.

TABLE 8
LUMINESCENCE OF MINERALS FROM AMELIA, VIRGINIA

Name of mineral	Color and structure	Locality	Response to ultraviolet radiation	Response to heat
Albite	White, argentite type inclosing nodules of spessartite. White to blue-green cleavelandite type. Bluish-gray splintery cleavage pieces.	Morefield mine. Rutherford mine. Rutherford mine.	Negative. Negative. Negative.	Glow quietly with a white light. Glow feebly with blue-white light. Blue-white luminous glow. Also triboluminescent.
Calcite	Ivory-yellow, opaque to transparent amber. Small wedge-shaped pieces.	Rutherford mine.	Bright crimson.	Brilliant orange-colored persistent glow.
Chlorophane	Fluorite-green, very much fractured. Brittle.	Rutherford and Morefield mines.	Bright green glow persists after specimen is removed from the source of radiation.	Emerald green—very brilliant persistent glow. Also triboluminescent.
Microcline	White. Cleavage pieces.	Morefield mine.	Negative.	Feeble, white glow.
Microcline (amazonstone)	Green. Cleavage pieces.	Rutherford and Morefield mines.	Negative.	Feeble glow. Green color completely disappears below red heat.
Microcline	Olive and amber crystals.	Rutherford mine.	Negative.	Feeble, white glow.
Phenacite	White, massive.	Rutherford mine.	Negative.	Feeble, white glow.
Quartz	Smoky, massive.	Rutherford and Morefield mines.	Negative.	Feeble, white glow. Smoky color disappears below red heat.
Topaz	(1) White, massive. (2) Colorless, transparent.	Morefield mine.	Negative.	Pure white luminous glow.
Zircon	Wood-brown. Elongated radiating crystals.	Morefield mine. Rutherford mine.	Negative. Golden yellow.	Feeble, white glow. Negative.

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STEIGERITE, A NEW VANADIUM MINERAL*

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SUMMARY

A new yellow, hydrous aluminum vanadate, $\text{Al}_2\text{O}_3 \cdot \text{V}_2\text{O}_5 \cdot 6.5 \text{H}_2\text{O}$, which has been named steigerite, is here described. It is similar to, but is not a true analogue of the iron vanadate, fervanite, and like fervanite is from the uranium-vanadium claims along the north wall of Gypsum Valley, San Miguel County, Colorado.

OCCURRENCE

On a visit in 1932 to the uranium and vanadium claims owned by Sullivan Brothers of Nucla, Colorado, and located along the north wall of Gypsum Valley, the author collected several specimens of a bright yellow, more or less pulverulent mineral that coated cracks in the uranium- and vanadium-bearing sandstone. At the time of collection they were considered to be pascoite but later when found to be insoluble in water it was evident that the yellow mineral was not pascoite. Samples of this mineral collected by Frank L. Hess in 1921 and labelled pascoite with a question mark, had been held by him during this time awaiting analysis. He collected his material from the Ponto No. 3 claim which at that time was owned by the W. L. Cummings Chemical Company, and adjoins the Sullivan claims on the east.

To this new mineral the name steigerite is given in honor of Dr. George Steiger formerly chief chemist of the U. S. Geological Survey, whose chemical analyses are widely known and quoted.

The country rock, the Morrison (McElmo) sandstone, is heavily impregnated with oxidized vanadium minerals and has a mottled brownish to purplish black color. No individual segregations of the vanadium minerals were found that would yield suitable material for a definite determination of the mineral sequence, but using color as a basis and comparing the material with the type specimens of corvusite that were described from the Ponto No. 3 outcrop, it seems certain that the principal vanadium mineral in the sandstone at this place is corvusite.

A number of concentrations of vanadium minerals are some-

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what nodular in form. In the sandstone near the marginal limits of these nodules small fractures have developed, which in general are curved nearly parallel to the nodular body and pass through the sandstone independent of the bedding. Towards the outer edges of some of the vanadium-rich concentrations the fractures are more closely spaced than near the centers. It seems logical to conclude that these cracks are the result of some change of volume in the minerals. The best specimens of corvusite were slickensided with a fibrous appearing structure produced by the swelling of the mineral as it formed in the sandstone.

Steigerite, fervanite and gypsum fill the minute fractures in the corvusite concentrations and are the last vanadium minerals deposited. Thus it appears that the change which takes place in the vanadium minerals are probably due to oxidation and hydration. These changes have made necessary certain volume adjustments. The primary vanadium minerals of the sandstone are still unknown but the following sequence of vanadium minerals seems to be consistent with both occurrence and chemical reasoning.

Vanoxite	$2V_2O_4 \cdot V_2O_5 \cdot 8H_2O$
Corvusite	$V_2O_4 \cdot 6V_2O_5 \cdot ?H_2O$
Steigerite	$Al_2O_3 \cdot V_2O_5 \cdot 6.5H_2O$
Fervanite	$2Fe_2O_3 \cdot 2V_2O_5 \cdot 5H_2O$

In other places the solutions have apparently migrated farther than the limits of the vanadium-rich concentrations as occasional seams of the minerals steigerite and fervanite are found in the sandstone. These seams in general have the appearance of being the channels along which the most recent movements of vanadium solutions have taken place.

PHYSICAL PROPERTIES OF STEIGERITE

Steigerite has a bright canary yellow color. No crystallized specimens have been found, but in all the specimens so far examined the mineral has, to the unaided eye, a powdery appearance. Closer examination reveals a rather waxy luster and small fractures which resemble shrinkage cracks. With the aid of the microscope a slightly different texture is noticeable, including some flat plates, a crypto-crystalline fibrous type resembling chalcedony and again a nondescript gummy mass. Some of the properties indicate that this mineral may have been deposited as a colloidal precipitate.

Selecting the best of the yellow material and being careful to exclude any other vanadium minerals contained in the sandstone, a 0.75 gram sample was prepared. The chemical analysis, x-ray examination and index of refraction, were all determined upon this same sample.

The texture is such that only a mean index of refraction could be determined and although there is some variation in the values all were confined within the range of 1.700 and 1.715, so that until better material is available the mean index is given as $1.71 \pm .005$.

ANALYSIS OF STEIGERITE

E. P. Henderson, Analyst

	Percentages	Molecular ratios	
V ₂ O ₅	44.44	1	.2448
Al ₂ O ₃	25.14	1	.2460
Fe ₂ O ₃	1.50		.0094
H ₂ O—110°	8.08	6.5	1.6110
H ₂ O+110°	21.04		
	100.20		

Separate portions were tested qualitatively for silica, uranium and sulphates but none were found. Steigerite is easily decomposed by mineral acids and produces a solution with a deep cherry-red color. Steigerite was placed in a tightly stoppered flask filled with water and after three months time showed no appreciable solubility.

ARTIFICIAL STEIGERITE

Although the natural mineral is amorphous it was hoped that the synthetic steigerite could be prepared in the crystalline form. However, the artificial steigerite was amorphous and similar to the natural material in all its physical properties.

A soluble calcium vanadate was made by boiling hewettite or metahewettite, in saturated lime water. An aluminum sulphate solution was prepared by adding an excess of freshly precipitated aluminum hydroxide to sulphuric acid. These two solutions were then slowly siphoned off into a larger dish simultaneously. For details of the apparatus and procedure, see Johnston's¹ description of the diffusion processes in the preparation of pure substances.

The precipitate, steigerite, prepared in this manner was then

¹ Johnston, John, *Jour. Amer. Chem. Soc.*, vol. 36, p. 16, 1914.

transferred to a tall cylinder and repeatedly washed with water until the washings were free from sulphates.

The artificial steigerite was found to contain V_2O_5 44.89% and the loss on ignition at red heat was 31.83%. The V_2O_5 content agrees nicely with that of the natural mineral; however, the water content is slightly higher.

The following table permits a comparison of the loss of water for the natural and the artificial steigerite.

DEHYDRATION OF STEIGERITE

Temp.	Percentage loss of water		
	(1)	(2)	(3)
-110°	8.08	7.43	8.74
+110°	21.04	21.23	23.09
Molecular Ratios	1.616	1.59	1.76

(1) From sample analyzed.

(2) Determinations from another specimen.

(3) Artificial steigerite.

Comparing the total loss of water on the artificial material with the two natural mineral specimens, a rather close agreement is noticed. The degree of hydration is not, however, definitely settled. If the average ratio is taken of the total loss of water at red heat on the two natural samples, which had been exposed to the atmosphere in the Museum for over a year, the ratio of water to bases is 1:1:6.5.

In the artificial preparation the ratio between V_2O_5 and H_2O is 1:7.1. This suggests that the stable hydrate contains either 6.5 or 7 molecules of water. However, until a new locality for steigerite is found which will yield additional specimens for study the water content is being tentatively assigned as 6.5 molecules.

The x-ray examination made by Dr. E. Posnjak² shows that the natural steigerite is crystalline with a pattern which is distinctly different from fervanite. The artificial aluminum vanadate gave no distinct pattern, only faint, broad bands, which would indicate that the primary particles are exceedingly small, and that this material may be largely amorphous.

² Personal communication.

THE BIOTITE SYSTEM

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Ten years ago the writer published the results¹ of certain studies in the mica group and presented diagrams showing the approximate relations between variations in composition and in optic properties in certain parts of the group. At that time in dealing with biotites, the most difficult problem was to determine the correct end-member molecules, especially with respect to ferric iron and titanium; but they were both finally considered as proxying for magnesium. Since that time the writer has shown that ferric iron probably proxies for magnesium in chlorite;² Kunitz has demonstrated that ferrous iron in biotite can be changed artificially to the ferric state without destroying the crystal;³ Barnes has shown that the same change can be produced (and reversed) in hornblende,⁴ and that the change is accomplished by eliminating hydrogen and not by adding oxygen. Therefore the idea that ferric iron proxies for magnesium in biotites is no longer an assumption based chiefly on a study of the analyses, but is at least a reasonable theory. During the last few years, Machatschki⁵ and Jakob⁶ have adopted the view that titanium also probably proxies for magnesium, at least in large part.

It seems desirable to re-examine the data for the biotite system and revise the diagrams, partly because of new data (36 new analyses) and partly because a square diagram must be so constructed⁷ that if the molecules at the corners are A, B, C, and D, (A and C being at diagonally opposite corners), $50A + 50C$ must equal $50B + 50D$, since the central point of the square represents equal parts of A and C, and also represents equal parts of B and D. Therefore, it is incorrect to use $H_4K_2(Mg,Fe)_6Al_2Si_6O_{24}$ and $H_4K_2(Mg,Fe)_5Al_4Si_5O_{24}$ at the corners; it is necessary to use $5\{H_4K_2(Mg,Fe)_6Al_2Si_6O_{24}\}$ and $6\{H_4K_2(Mg,Fe)_5Al_4Si_5O_{24}\}$. A

¹ *Am. Jour. Sci.*, Vol. 9, pp. 309-327 and 415-430, 1925.

² *Am. Jour. Sci.*, Vol. 11, pp. 283-300, 1926.

³ *Zeit. Krist.*, Vol. 70, p. 508, 1929.

⁴ *Am. Mineral.*, Vol. 15, pp. 393-417, 1930.

⁵ *Cent. Min.*, 1930, pp. 191-200 and 255-267.

⁶ *Zeit. Krist.*, Vol. 82, p. 271, 1932.

⁷ Dr. N. L. Bowen kindly called the writer's attention to this method of testing a square diagram.

comparison of the diagram (Fig. 2) now presented with that published ten years ago shows that this change has very little effect on the position of the lines representing optic properties, although the point representing any given analysis is shifted somewhat toward the left margin.

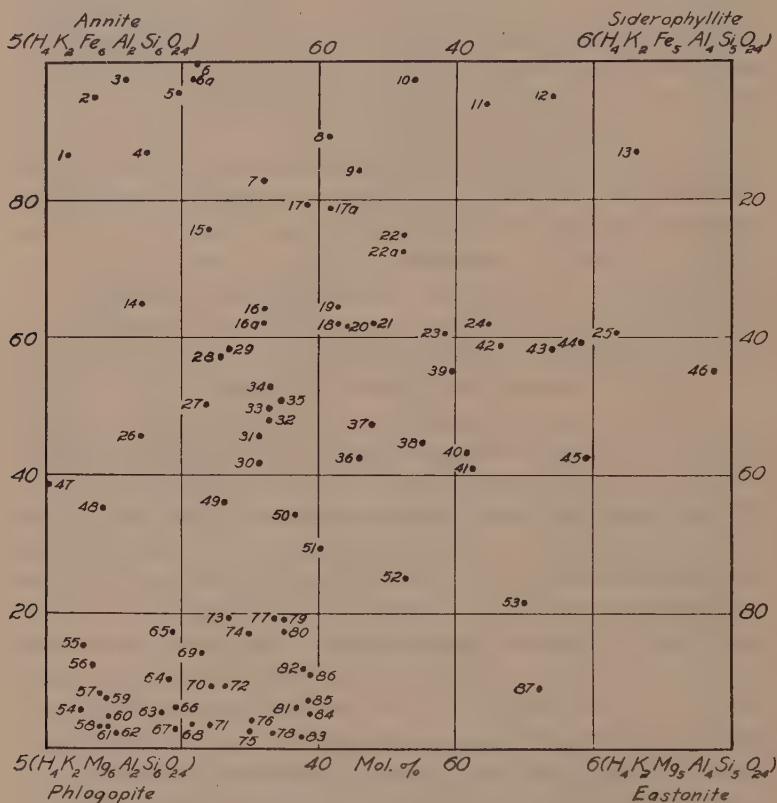


FIG. 1. Variations in composition in the biotite system.

REFERENCES FOR BIOTITE ANALYSES, FIG. 1

No. 1 is Doelter's 160 (*Hdb. Mineralch.*, II, 2, 1917, p. 680). No. 2=Doelter's 181. 3, S. Weidman: *Wis. Geol. Surv. Bull.*, vol. 16, 1917, p. 295, and F. F. Grout: *Am. Mineral.*, vol. 9, 1924, p. 159. 4=D. 81. 5, G. Schauburger: *Cent. Min.*, 1927, A, p. 89. 6=D. 178. 6a, S. Weidman: *loc. cit.*, p. 295. 7, W. Wahl: *Fennia*, vol. 45, 1925, No. 20, p. 80, 83-88. 8, B. Koto: *Jour. Geol. Soc. Tokyo*, 26, 1919, p. 407 and 7. 9=D. 19 (p. 725). 10=D. 23 (p. 726). 11=D. 115. 12=D. 114. 13=D. 168. 14, W. Kunitz: *Zeit. Krist.*, vol. 70, 1929, p. 508, No. 4 (=Kunitz 1). 15=D. 166. 16=D. 78. 16a, F. F. Grout: *Am. Mineral.*, vol. 9, 1924, p. 159, No. 3. 17=D. 171.

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In calculating biotite analyses, lime has been omitted, since Jakob⁸ and Kunitz⁹ have shown that micas contain little, if any, lime. It may be that biotite (as originally formed) contains some ferric iron, but it seems probable that biotites contain much ferric iron only as a result of oxidation of ferrous iron in the crystal by natural processes, and, for simplicity, all ferric iron has been calculated as if it were ferrous iron (that is, Fe_2O_3 is considered to be equal to two FeO). Manganese monoxide is also calculated as ferrous oxide. Since the studies of Jakob¹⁰ and Machatschki¹¹ indicate that titanium proxies chiefly for magnesium, in spite of the marked difference in valence, it has been calculated with ferrous iron, as it was in the study made ten years ago. Fluorine is cal-

⁸ *Zeit. Krist.*, vol. **61**, p. 155; vol. **62**, p. 433; vol. **64**, p. 430; vol. **69**, p. 217; vol. **69**, p. 403; vol. **69**, p. 511.

⁹ *Zeit. Krist.*, vol. **70**, p. 508, 1929.

¹⁰ *Zeit. Krist.*, vol. **82**, p. 271, 1932.

¹¹ *Cent. Min.* **1930**, pp. 191-200, 255-267.

culated as equivalent to hydroxyl. Soda is calculated as equivalent to potassa. In all these cases the basis of calculation is, of course, molecular proportion and not weight percentage.

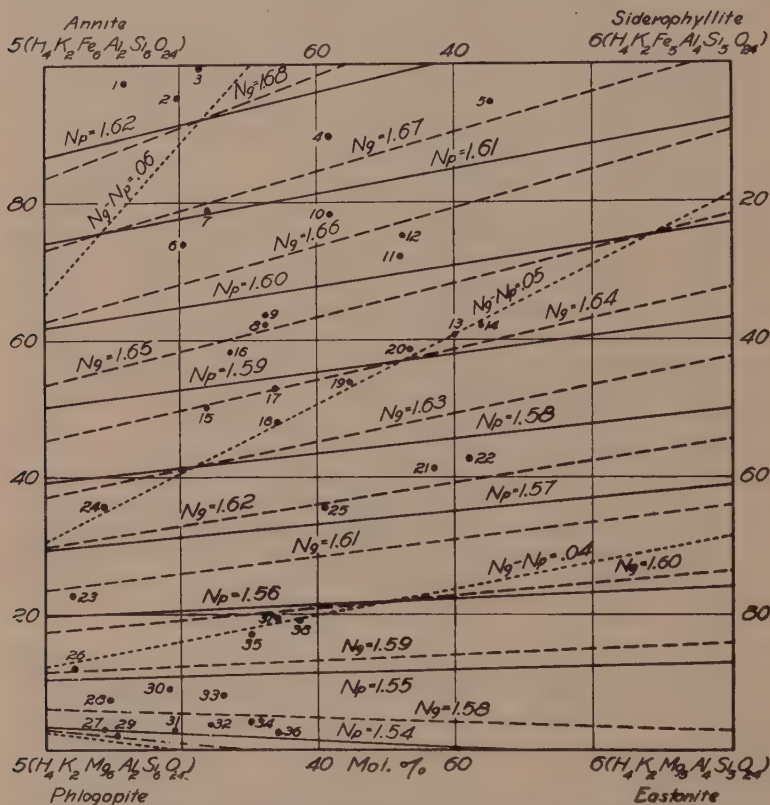


FIG. 2. Variations in composition and optic properties in the biotite system.

REFERENCES FOR FIG. 2

1. F. F. Grout: *Am. Mineral.*, vol. 9, 1924, p. 159. No. 7. $N_g=1.677$, $N_p=1.612$.
2. G. Schaubberger: *Cent. Min.*, 1927, A, p. 89. $(-)2V=21^\circ \pm$; $N_g=1.697$, $N_p=1.616$.
3. F. F. Grout: *loc. cit.*, No. 9. $N_g=1.677$, $N_p=1.623$.
4. B. Koto: *Jour. Geol. Soc. Tokyo*, vol. 26, 1919, p. 407. $N_g=1.672$, $N_m=1.671$, $N_p=1.614$.
5. F. F. Grout: *loc. cit.*, No. 8=Doelter's 115. $N_g=1.672$, $N_p=1.618$.
6. W. Kunitz: *N. Jahrb. Min. Bl. Bd.*, 50, 1924, p. 365, No. 12 (p. 386) $N_g=?$, $N_p=1.605$.
7. F. F. Grout: *loc. cit.*, No. 10. Rammelsberg's analysis. $N_g=1.672$, $N_p=1.614$.

8. H. v. Eckermann: *Tsch. Min. Pet. Mit.*, vol. 38, 1925, p. 277, $2V=11^{\circ}26'$, $N_g=1.6311$, $N_m=1.6305$, $N_p=1.5887$.
9. F. F. Grout: *loc. cit.*, No. 3, $N_g=1.655$, $N_p=1.605$.
10. F. F. Grout: *loc. cit.*, No. 10, Schläpfer's analysis. $N_g=1.672$, $N_p=1.614$.
11. F. F. Grout: *loc. cit.*, No. 4, $N_g=1.664$, $N_p=1.610$.
12. W. Kunitz: *loc. cit.*, No. 4 (p. 386) $N_g=?$, $N_p=1.598$.
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14. J. Jakob: *loc. cit.*, No. 60, $N_g=1.634$, $N_p=1.543$.
15. F. F. Grout: *loc. cit.*, No. 11=Doelter's 142. $N_g=1.655$, $N_p=1.592$.
16. H. W. Turner: *Am. Jour. Sci.*, vol. 7, 1899, p. 294, No. 1743. A. N. Winchell: *Am. Jour. Sci.*, vol. 9, 1925, p. 309, $N_g=1.647-1.653$, $N_p=1.588-1.593$.
17. J. Jakob: *loc. cit.*, No. 61, $N_g=1.625$, $N_p=1.589$.
18. H. W. Turner: *loc. cit.*, No. 1751. A. N. Winchell: *loc. cit.*, $N_g=1.638$, $N_p=1.588$.
19. F. F. Grout: *loc. cit.*, No. 2, $N_g=1.640$, $N_p=1.597$.
20. W. Kunitz: *loc. cit.*, No. 10, $N_g=?$, $N_p=1.588$.
21. J. Jakob: *loc. cit.*, No. 57, $N_g=1.642$, $N_p=1.546$.
22. E. Zschimmer: *Inaug. Diss. Jena*, 1898. *Zeit. Krist.*, vol. 33, 1900, p. 491. Given by Doelter as No. 6 on p. 722. $(-)2E=23^{\circ}-30^{\circ}$, $N_g=1.62$, $N_m=1.60$, $N_p=1.58$. $\{N_g$ and N_m must be very nearly equal since $(-)2E=23^{\circ}-30^{\circ}\}$.
23. S. Kozu and S. Tsurumi: *Proc. Acad. Tokyo*, vol. 9, 1933, p. 265. $(-)2E=23^{\circ}-32^{\circ}$, $N_g=1.606$, $N_p=1.557$.
24. F. F. Grout: *loc. cit.*, No. 1 $(-)2V=\text{small}$. $Y=b$, $N_g=1.630$, $N_p=1.580$.
25. W. Kunitz: *loc. cit.*, No. 9, $N_g=1.610$, $N_p=1.5705$.
26. F. F. Grout: *loc. cit.*, No. 12, $N_g=1.585$, $N_p=1.550$.
27. W. Kunitz: *loc. cit.*, No. 4. $N_g=?$, $N_p=1.5385$.
28. H. v. Eckermann: *loc. cit.*, $(-)2V=4^{\circ}30'$, $N_g=1.5795$, $N_p=1.5452$.
29. W. Kunitz: *loc. cit.*, No. 2. $N_g=1.5664$, $N_p=1.5338$.
30. H. v. Eckermann: *loc. cit.*, $(-)2V=6^{\circ}20'$, $N_g=1.5801$, $N_g=1.5506$.
31. J. Orcl: *Bull. Soc. Fr. Min.*, vol. 48, 1925, p. 362, $(-)2V=0^{\circ}$, $N_g=1.5919$, $N_p=1.5529$.
32. W. Kunitz: *loc. cit.*, No. 5, $N_g=?$, $N_p=1.5466$.
33. W. Kunitz: *loc. cit.*, No. 6, $N_g=1.5845$, $N_p=1.5498$.
34. W. Kunitz: *loc. cit.*, No. 3, $N_g=1.577$, $N_p=1.5432$.
35. W. Kunitz: *loc. cit.*, No. 7, $N_g=1.5942$, $N_p=1.5580$.
36. W. Kunitz: *loc. cit.*, No. 1, $N_g=1.582$, $N_p=1.5451$.
37. W. Kunitz: *loc. cit.*, No. 8, $N_g=?$, $N_p=1.5594$.
38. H. S. Washington: *Am. Jour. Sci.*, vol. 14, 1927, p. 173. $(-)2V=20^{\circ}$, $N_g=1.61-1.62$, $N_p=1.56-1.57$.

There are some analyses of biotite which can not be calculated according to these rules into $H_4K_2(Mg,Fe)_6Al_2Si_6O_{24}$ and $H_4K_2(Mg,Fe)_5Al_4Si_5O_{24}$ without large discrepancies, which may be due to seriously impure samples or unreasonably large errors in the analyses. On the other hand many of the best analyses give small discrepancies. In practically all analyses of biotite the $Al_2O_3:SiO_2$ ratio lies between 1:3 (as in the first formula) and 2:5 (as in the

second formula). Basing the calculation of the two molecules on this ratio, there will result an excess or deficiency of MgO (including FeO, MnO, Fe_2O_3 and TiO_2). Ordinarily there will also be certain discrepancies in K_2O and H_2O . In Figure 1 no analyses have been used which gave a discrepancy greater than 55 mols of MgO (corresponding with 2.2 weight per cent MgO), and this discrepancy is less than 40 mols except in analyses numbered 12, 14, 17a, 19, 26, 30, 33, 39, 46, 47, 51, 60, 72, 74, and 87. Discrepancies in H_2O (+F) are not considered very important for present purposes. Discrepancies in $(\text{K}_2\text{O} + \text{Na}_2\text{O})$ are surprisingly large in some cases, but they are less than 32 mols (or about two per cent Na_2O by weight) except in Nos. 19, 23, 28, 40, 44, 45, 49, and 87.

If the theory here presented as to the composition of biotite is correct, then much (or all?) of the ferric iron in biotite was originally ferrous iron, and has been oxidized by natural processes. This is most clearly evident when analyses containing high tenors of ferric iron are considered; to calculate these analyses into the molecules used in this discussion it is necessary to consider the ferric iron as equivalent to ferrous iron, a condition well illustrated in analyses 1, 4, 5, 11, 12, 16, 19, 20, 38, and 46; each of these analyses has more than ten per cent of Fe_2O_3 by weight.

In Figure 2 at first only those analyses (accompanied by measures of refractive indices) were plotted which could be calculated into the molecules used in this study with a discrepancy less than 55 mols of MgO (or 2.2 per cent by weight); then it was discovered that analyses with a greater MgO discrepancy gave equally good agreement between measured and indicated optic properties, except in numbers 14 and 21, in which the refractive indices, as measured, are clearly abnormal, since they indicate a birefringence of .091 and .096, respectively, whereas no other biotites of similar composition are known to have a birefringence greater than .05 to .06. Those added to the figure in this way are numbers 4, 7, 13, 14, 19, 20, 21, 25, and 26.

In Figure 2, showing the relations between composition and optic properties, No. 1 (Grout's lepidomelane from Wausau, Wis.) has an index which corresponds with about 15 per cent less Fe than reported in the analysis, but the sample, optically measured, is only from the same locality (and not necessarily from the same sample) as that which was analyzed.

No. 31 (Orcel's phlogopite from Utah) has an index and a bire-

fringence which correspond with about ten per cent more Fe than shown by the analysis. This may be due to the fact that the sample is variable in color (and therefore doubtless in composition and properties) and the palest part was used for the analysis.

No. 38 (H. S. Washington's phlogopite from Italy) also has an index and birefringence indicating about 10–15 per cent more Fe than shown by the analysis, but the indices were measured only approximately as shown by the record ($N_g = 1.61\text{--}1.62$, $N_p = 1.56\text{--}1.57$).

In all other cases discrepancies between the diagram and measures of the minimum index of refraction are less than 0.01.

The birefringence has not been measured in samples 6, 12, 20, 27, 32, and 37. Samples in which the measured birefringence differs from that indicated by the diagram by more than 0.01 are No. 2 (Schauberger's biotite from Brevik, Norway— $N_g - N_p = .081$) and No. 8 (Eckermann's biotite from Mansjö Mt., Sweden— $N_g - N_p = .0424$).

It is clear that some variations between indicated and actual optical properties must be expected, since the diagram makes no attempt to show the effects upon the optical properties of variations in tenor of water, or fluorine, or soda, and makes no distinction between titanium, manganese, ferrous iron, and ferric iron, in spite of the fact that Kunitz has shown that oxidation of ferrous iron in biotite raises the index, N_g , for example, from 1.667 to 1.718 for a change from 6.51 Fe_2O_3 and 17.83 FeO in natural biotite to 24.89 Fe_2O_3 in the same mineral after heating.

THE OCCURRENCE AND ORIGIN OF CELESTITE AND FLUORITE AT CLAY CENTER, OHIO

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Ithaca, New York.*

Celestite has been recorded from the Lower Helderberg rocks at a number of localities in the eastern United States, including Syracuse, Lockport, Jamesville, and Auburn in New York State (5) (10), Drummond and Maybee, Michigan (9), Put-in-Bay (8) and Clay Center, Ohio, and Mineral County, West Virginia (13).

The Put-in-Bay deposits are well known, because the caves at that locality have provided a number of large crystals, but the Clay Center occurrence is particularly interesting, not only because of the abundance of celestite, but also because of the associated minerals, especially fluorite.

These minerals are found at Clay Center in the Guelph member of the Niagara group. Higher strata have been eroded at this locality, but in other parts of Ottawa County, these uppermost Niagara beds (known in Ohio as the Cedarville-Springfield dolomite) are overlain unconformably by the last westerly remnants of the Salina.

The rock exposed in the quarry is a buff or brownish-yellow dolomite of granular texture and porous to cavernous structure, which forms evenly bedded strata having an individual thickness of several feet.

These beds are regarded as the probable equivalent of the Huntington dolomite of Indiana, the Guelph or Racine dolomite of Wisconsin, the Racine and Port Byron of Illinois, and the upper part of the Engadine dolomite of Michigan (3) (10) (12).

In thin section the rock is seen to consist almost entirely of pure dolomite grains, slightly clouded by argillaceous matter, with almost no calcite. Large detrital grains, mostly quartz, have been observed only in certain greenish-gray beds found sparingly in the lower level of the quarry.

Dolomitic grains bordering the frequent small solution cavities may have clear euhedral faces developed on their exposed sides, while the central portions of the grains are clouded as usual (Fig. 1). Calcite crystals with curved faces, due probably to a slightly magnesian character are occasionally found in the larger cavities.

The dolomite contains many fossils, usually preserved as casts

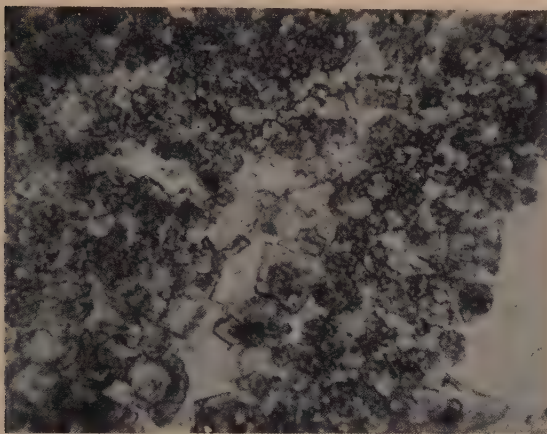


FIG. 1. Cedarville-Springfield dolomite from Clay Center, Ohio; coarse, cavernous phase, showing zoned development of crystal faces in cavities. Plane polarized light, $\times 27$.

only, which in part accounts for the cavernous structure of the rock. The corals are most frequently replaced by dolomite (Fig. 2). Practically no shells of mollusca or brachiopods replaced by this mineral were noticed.

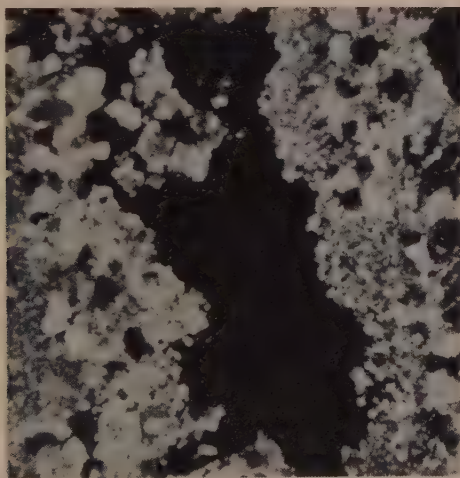


FIG. 2. Cedarville-Springfield dolomite, showing replacement along septae of a coral (*Diplophyllum caespitosum*). Crossed nicols, $\times 27$.

The northeastern part of the quarry shows evidence of a flat dome-like structure, which may be of depositional rather than tectonic origin. The known prevalence of coral reefs in the upper Niagara suggests that the former cause is the more probable (3).

Both regular jointing and evidences of faulting are absent.

MINERAL OCCURRENCES

Celestite. Celestite occurs mainly in roughly lenticular masses, from a few inches to several feet in breadth, with the longer dimensions commonly parallel to the bedding; and the celestite-bearing zones, which are rarely of any great horizontal extent, appear to occupy solution cavities.

The mineral occurs much more abundantly in the upper than the lower beds, and is at present particularly concentrated in the northeastern corner of the quarry, where the beds show a slight doming. Not only is more celestite present, and in larger crystals, but cavities, both filled and unfilled are larger and more numerous in this section. If the doming is the result of orogenic stresses, the resultant tension in the uppermost strata may have facilitated the development of solution cavities and replacement bodies at this location.

In the lower level the rock is less cavernous, and celestite is not so frequently found, but when present is observed to be in flat blade-like crystals, or in compact crystalline masses. Here also cavities are sometimes found filled with clay, which may contain celestite crystals. A border of white crystalline celestite may surround these pockets.

The crystals observed in the quarry range from pale blue to white and colorless. When first exposed, the larger ones are frequently bluish, sometimes quite deeply tinted, but after exposure to light and weather they become either white or colorless. Thin bladed crystals are by far the most abundant. Stout tabular ones are less common, but are occasionally observed in the larger vugs and pockets in the upper beds.

Spectroscopic analysis shows no metallic elements other than strontium in the Clay Center celestite.

Fluorite. Fluorite is much less abundant at Clay Center than celestite, and was observed by the writer in only two sections of the quarry. The mineral is found for a short distance along the southern end of the east wall, in the upper level. This is in the oldest part of

the quarry, and, since specimens are highly prized by collectors, most of the supply at this point has disappeared. The other deposit is found in a narrow zone along the bottom of the northern portion of the western wall of the lower level. These two occurrences do not seem to be connected, and, until further excavation is done, sufficient evidence is lacking to say that a fluorite zone is present, striking northwest-southeast.

The fluorite is found in irregular bodies, almost invariably associated with celestite, and in part replacing the dolomite. Vugs lined with fluorite crystals are common. Some of the large masses recently discovered in the lower level consist of massive brown fluorite interpenetrated by bladed white celestite.

A small quantity of purple fluorite can be observed in a vein-like mass of celestite near the top of the north end of the eastern quarry face, upper level. The mineral occurs in small anhedral grains disseminated sparingly through bladed celestite. All of the massive fluorite and most of the crystals found in the quarry are dark brown in color. Some of the crystallized material exhibits various lighter shades of brown and yellow, ranging to nearly colorless. The darker crystals are commonly zoned, with the centers always darker in hue than the outer portion. The faces of the cubes vary from less than one-eighth inch to one-half and rarely up to an inch and a half on edge.

Both the color and the striking photo-luminescence of the fluorite in this deposit seem due to included bituminous matter. Pure, colorless fluorite fluoresces with a white light under ultra-violet rays from a mercury vapor lamp. Hydrocarbons, such as crude oil, mineral oil, and petrolatum fluoresce with a deep yellow light. It is interesting to note that the intensity and hue of fluorescence of the Clay Center fluorite vary from whitish yellow towards a very strong clear yellow in direct proportion to the intensity of the brown color (under ordinary light). The fluorescence of this material is identical to that of fluorites containing petroleum inclusions (4). Under the recently developed argon glow lamp fluorescence of Clay Center fluorite varies from deep orange yellow for light brown or amber crystals, to strong greenish yellow for the dark brown massive material. Similar results have been obtained by E. M. Gunnell (4).

Phosphorescence is exhibited for about half a minute after exposure of the mineral to strong ultra-violet light. Heating or crush-

ing does not cause phosphorescence, though some other fluorites emit light after such treatment (4).

Upon heating to redness the brown fluorite changes to gray, while the yellow material becomes almost colorless. Heating for several hours at temperatures gradually increasing up to 500°F. does not cause any change in color. That the color change by heating is due to volatilization (and perhaps carbonization) of bituminous matter is, of course, not conclusive, since some metallic oxides might behave similarly. To further test for the presence of such oxides, a spectroscopic analysis of the dark brown fluorite was made. Strontium was found present in the order of 0.1 to 1.0 per cent, but all heavy metals were absent. The results of this analysis indicate that the brown coloration is due to included bituminous matter.

Calcite. Curved calcite crystals, colorless, or clear with a slight yellowish tint, are frequently found lining cavities in the dolomite. They vary from minute drusy individuals to those an inch or more in diameter. Spectroscopic analysis shows considerable strontium (around 1 per cent strontium) and magnesium (in the order of 1.0 to 5.0 per cent magnesia) replacing the calcium, which may account for the curved faces. Part of the curvature can be explained, however, by the development of scalenohedral faces on the acute rhombohedrons constituting the basic form. Slight etching somewhat obscures the interfacial angles.

Other Minerals. Minute drusy pyrite (marcasite?) crystals with remarkable iridescence (peacock blue, bronze red, greenish-yellow, purple, etc.) occur sparingly. They are found lining cavities in the dolomite, but can be observed only in the freshly quarried material, since they alter rapidly to limonite. The principal occurrence at present is in a zone in the eastern portion of the lower level.

Very rare and small masses of sphalerite have been found along the east wall of the quarry. The typical material is dark reddish brown in color, and is imperfectly crystallized. It appears to occupy former solution cavities in the dolomite, and partly replaces the rock.

A small pocket of snowy white gypsum has been reported from the lower level. At the time of the writer's visit, however, no occurrences of this mineral were observed. Small inclusions of anhydrite in bladed celestite have occasionally been noted in thin sections.

ORIGIN OF THE CEDARVILLE-SPRINGFIELD DOLOMITE

The abundance of coral and stromatoporoid remains in the Cedarville-Springfield dolomite indicates that this formation was deposited in a warm, clear, shallow sea, and also that in the deposition direct chemical precipitation was very slight or non-existent.

Dolomitization was the result of concentration of magnesium carbonate relative to calcium carbonate, and then of the union of the two carbonates to form the stable double salt, dolomite. The increase in magnesium carbonate may have been brought about by (a) leaching of the calcium carbonate, or by (b) replacement of the calcium carbonate by magnesium carbonate from the sea water. It seems probable that the former process was chiefly effective in the formation of the Cedarville-Springfield dolomite, though the latter process may also have contributed. The aragonitic hard parts of the organisms were most readily susceptible to either leaching or replacement, and hence may well have been more important in the dolomite production than the calcitic ones containing magnesium carbonate. Leaching of the calcium carbonate occurred after the elevation and exposure to the atmosphere of the Guelph sediments at the end of the Niagara epoch. Most of the cavernous structure of the rock may have been developed at that time.

ORIGIN OF THE CELESTITE

Celestite is known to be deposited by both magmatic and meteoric waters.

Deposits of the former type are usually found associated with igneous rocks or faulting, but since neither of these are present at Clay Center or in its vicinity, a magmatic source hardly seems likely.

Deposits of celestite as a primary constituent of sedimentary formations are not uncommon, and frequent associates are such minerals as gypsum, salt, and other salines: all of which are formed under semi-arid or arid conditions.

Occurrences of this type have been described from California (6, 11, 1) and Arizona (11). Celestite of sedimentary origin is also recorded from the Monroe formation of the Lower Helderberg (11). The deposits are frequently associated with dolomites or magnesian limestones.

The celestite may form a high percentage of the bed in which it occurs, or, as in the case of the Bass Island of the Monroe group in Michigan, and the Vermicular limestone of the same group in New York, the crystals are distributed through a fine-grained ground mass (8) (7). The sharp boundaries of the cavity walls left after the crystals were dissolved are considered by Kraus to indicate the slow formation of the crystals in unconsolidated sediments. They were therefore chemically precipitated. The lack of fossil remains in the authigenic celestite-bearing beds, in addition to the association of some with salt or gypsum all point to precipitation from water of high salinity.

Although celestite has been observed in slight amounts at least in all of the world's salt deposits (1), an unusually high concentration of it must have been present to yield deposits like some of those found in the southwest or even in the Bass Island beds. The cause of this concentration is not readily understood.

The solubility of celestite is moderately high, it being seven times more soluble than calcite in ordinary water. Solutions containing halides such as NaCl , MgCl_2 , or CaCl_2 markedly increase the solubility. Celestite is less soluble than gypsum, hence when present may be the first formed of the saline residues.

The primary celestite present in any formation may through leaching by meteoric waters be carried into the lower beds of that formation, as at Put-in-Bay, Ohio, or into a lower lying formation before it is redeposited.

The widespread occurrence of celestite in the Bass Island formation has been pointed out and also the ease with which the mineral passes into solution, especially if halides are present. It is probable that the celestite at Clay Center was leached from the overlying Bass Island beds, and subsequently redeposited in the cavities in the Cedarville-Springfield dolomite, or also partly replacing the rock (Fig. 3). It is doubtful whether strontium-extracting organisms existed during Guelph times capable of depositing this element in the Cedarville-Springfield dolomite in the large quantities found at Clay Center. Since Clay Center is situated near the top of the Cincinnati Arch, it is probable that the Salina beds normally lying between the Niagara and Monroe groups were either absent or very thin, and that at this locality the Monroe rocks almost directly overlaid the Cedarville-Springfield dolomite.

It is of interest to note that Kraus has described a celestite occurrence near Maybee, Monroe County, Michigan (9), which is similar to that at Clay Center. In this case, the celestite occurs as crystalline masses in a porous dolomite, which is overlain by Bass Island beds rich in primary celestite.

ORIGIN OF THE FLUORITE

The reasons for not considering the Clay Center celestite to be of igneous origin apply also to the fluorite.

Fluorine is a minor constituent of most organisms, tending to be found in association with calcium phosphate (5). It is more promi-

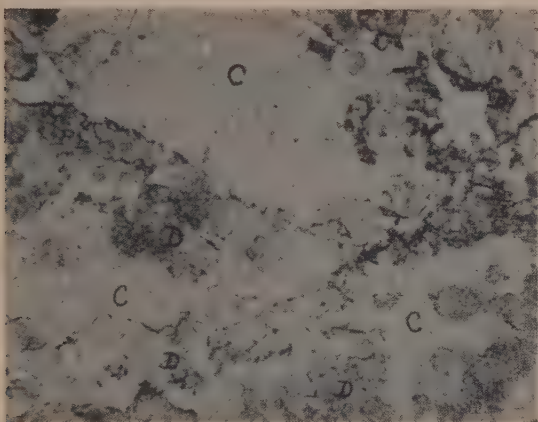


FIG. 3. Showing replacement of Cedarville-Springfield dolomite by celestite. Plain light, $\times 27$. (C = celestite; D = dolomite.)

nent in marine than in fresh water forms, though most marine invertebrates contain only traces of this element (2). Oyster shells may contain as much as .012% fluorine, and Dana reports an average of 0.25% fluorides in corals (2). Limestones are especially apt to have a small fluorine content, and this element may be a much more common constituent of these rocks than it is ordinarily considered to be, since it is rarely determined quantitatively. In some the percentage of calcium fluoride is pronounced. Fluorite crystals occur in cavities in the Niagara group at Niagara Falls, Welland County, and elsewhere in southwestern Ontario (14). It is also found in the Lower Carboniferous limestone at St. Louis, Missouri.

Murray and Renard (5) have proposed the theory that the high fluorine content of fossil bones and teeth from deep sea deposits is due to slow double decomposition between the phosphatic bone material and fluorides in solution in the sea water. Carnot (5) found that bone fragments increase notably in fluorine content after immersion in weak sodium fluoride solutions. He believes that the tendency for such phosphatic calcareous remains to take up fluorine from solutions containing small amounts of fluorides accounts for the high fluorine content of fossil bones as compared with that of modern bones. Evidently the phosphates present in lime sediments are of importance in determining their ability to absorb fluorine from sea waters.



FIG. 4. Celestite and fluorite replacing Cedarville-Springfield dolomite. Crossed nicols, $\times 27$. (C=celestite; F=fluorite; D=dolomite.)

In spite of the prevalence of calcium fluoride in limestones and marine organisms, primary sedimentary deposits contain the mineral only in small quantities. The notable concentrations appear to be found almost entirely in areas where evidences of igneous activity have been observed. Primary sedimentary fluorites of even moderate purity have not been reported. Secondary concentration has been important in the formation of the richer deposits of sedimentary origin.

Calcium fluoride, although a relatively insoluble compound,

lends itself to concentration by meteoric waters. It is eight and one-third times less soluble in water at ordinary temperatures than celestite. As compared with calcite, fluorite is much less soluble in cold water, though it is more soluble than barite, which is thought to be sometimes concentrated by meteoric waters. Though the exact manner in which fluorite is dissolved, transported, and re-deposited by meteoric waters is not well understood, we have undoubted proof that this process does occur.

Fluorite is known to occur in considerable quantities along with the celestite in the Put-in-Bay dolomite of the Monroe series. The fluorite found at Clay Center may either have been derived from the overlying Bass Island, as was the celestite, or through concentration of fluorides present in the Niagara dolomite itself. The bodies at Clay Center are undoubtedly secondary, since they partly replace the walls of the cavities in which they occur.

Thin sections show the celestite to be definitely earlier than the fluorite, and extensively replacing the dolomite (Fig. 3). The former appears to have first been introduced along solution cavities, and then to have replaced the walls. Fluorite exhibits a weaker tendency towards replacement than the celestite. It appears filling interstices between celestite crystals (Fig. 4) or lining cavities more often than replacing the dolomite.

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A RAPID METHOD FOR THE DETERMINATION OF PLAGIOCLASE BY THE FEDOROV UNIVERSAL STAGE

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INTRODUCTION

A feldspar on the Fedorov universal stage, which has four axes of rotation, cannot be turned directly into the position for which the three principal optical directions coincide with the two horizontal and the vertical axes of the microscope respectively, that is into the position of proper orientation. In determining a feldspar, formerly, at least two optical symmetry planes must be located separately, and the optical orientation can be determined only after the completion of the stereographic projection. In 1929 R. C. Emmons¹ modified the Fedorov stage by adding an inner east-west horizontal axis between the inner vertical axis and the north-south axis. The position of orientation is then easily obtained by placing one optical symmetry plane vertical and parallel to the inner east-west (I. E-W) axis, and then tilting the section on the (N-S) axis to the position where the section remains at extinction on rotation about the outer east-west (O. E-W) axis. A method used in the author's laboratory overcomes the tedious procedures, and the position of orientation may be obtained directly on the old Fedorov stage.

POSITION OF ORIENTATION

The present method of operation may be explained by the aid of Figure 1. When the first optical symmetry plane is set in the

¹ Emmons, R. C., A modified universal stage: *Am. Mineral.*, vol. **14**, No. 12, 1929; Plagioclase determination by the modified universal stage: *Am. Mineral.*, vol. **19**, No. 6, 1934.

north-south vertical position in the usual way, two principal optical directions (say α and β) are in this plane, one being inclined southward and the other northward. In order to bring the principal axis α to the microscopic axis, that is the center of the projection, the section is rotated counter-clockwise about the (I-V) axis, which has been inclined toward P, until α meets the (E-W)

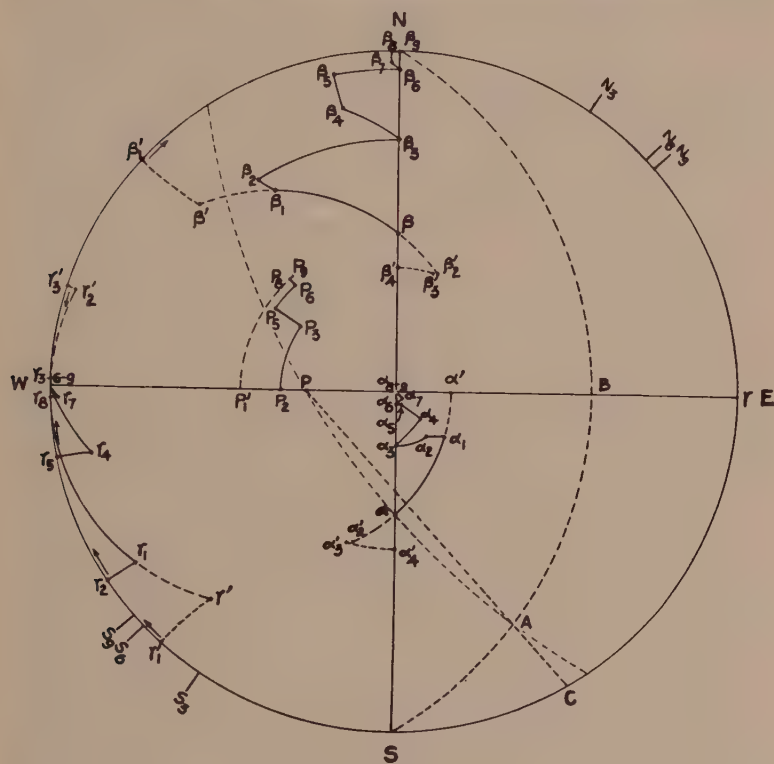


FIG. 1

axis at α' , β goes to β' , and γ to γ' . The angle of rotation is equal to the great circular arc AB. Then the section is tilted on the (N-S) axis with the left side downward until α' coincides with the center of the projection, and β' and γ' fall on the circumference at β_1' and γ_1' respectively. The normal of the section will go from P to the point P_1' . When the section is rotated clockwise about the (O-V) axis so that β_1' and γ_1' coincide with β_9 and γ_9 respectively, it is always at extinction on the rotation about the (E-W) axis.

The point P_1' will coincide with the point P_9 , and the (N-S) axis with the N_9S_9 line. A position of orientation is obtained.

However, as the position of α is not previously known, there is only the method of trial to reach the required position by the following procedures. The section is first rotated a convenient angle on the (I-V) axis (counter-clockwise in this particular case), so that α goes to α_1 , β to β_1 , and γ to γ_1 . It is evidently not in the position of extinction, for the optical symmetry plane $\alpha_1\beta_1$ is slightly inclined toward the northeast. Then the optical symmetry plane is returned into the north-south vertical position by the mutual movements on the (O-V) and (N-S) axes. When the α - β plane is vertical the mineral must always be in extinction on the rotation of the (E-W) axis.² The movements are equivalent to tilting on the (N-S) axis so that the principal optical axes are transferred to α_2 , β_2 , and γ_2 , followed by rotating on the (O-V) axis to α_3 , β_3 , and γ_3 . The normal of the section goes from P_2 to P_3 , and the (N-S) axis to the N_3S_3 line. α_3 is evidently nearer to the center of the the projection than in the preceding position, and if the section is rotated 90° either clockwise or counter-clockwise about the (O-V) axis to the second position of extinction, a rotation about the (E-W) axis will prove that the intensity of the interference color must be lower than that when the preceding position was brought to the direction of the (E-W) axis. When the optical symmetry plane is returned into the north-south vertical direction, the section is continued by the rotation about the (I-V) axis for a convenient angle in the same direction as before, and the plane $\alpha_3\beta_3$ is changed into the position of $\alpha_4\beta_4$, which is inclined again toward the northeast. Consequently the section does not remain at extinction. By the mutual movements of the (O-V) and (N-S) axes as before, the latter of which is in the direction of the N_3S_3 line, the optical symmetry plane reaches again the north-south vertical position, and the principal optical axes pass by the successive points α_4 , α_5 , β_4 , β_5 , γ_4 and γ_5 , and reach the positions of α_6 , β_6 and γ_6 . The normal of the section will be turned from P_5 to P_6 , and the (N-S) axis to the N_6S_6 line. α_6 is evidently nearer to the center, and the same test as before will prove that the interference color must be much lower than that in the preceding position. By con-

² If the (O-V) axis is rotated too much, the movement of the (E-W) axis is often prevented by the vertical graduated arcs, which may be unscrewed or folded if necessary.

tinuing the successive movements as stated above, the principal optical axis α will move gradually from the positions $\alpha_1, \alpha_2, \alpha_3 \dots$ etc. until it reaches the center of the projection, when both β and γ reach the circumference at β_9 and γ_9 , and are parallel to the NS and EW lines respectively. The normal of the section will go to the point P_9 , and the (N-S) axis to the N_9S_9 line. The angles of rotation on the (I-V), (N-S) and (O-V) axes determine the position of orientation with respect to the section.

Care must always be taken that after the section begins to be rotated about the (I-V) axis, the tilting on the (N-S) axis should be very small, for a large rotation on the (I-V) axis does not cause, in general, the optical symmetry plane to incline greatly, especially when the principal optical axis is near the vertical position.

If the section is rotated about the (I-V) axis in the wrong direction, or clockwise in this particular case, α will be transferred to α_2', β to β_2' , and γ to γ_2' . When the optical symmetry plane is brought to the north-south vertical position $\alpha_4'\beta_4'$ by the mutual movements on the (O-V) and (N-S) axes, α_4' is farther away from the center than in the preceding position, and consequently a stronger intensity of the interference color can be seen during rotation about the (E-W) axis as the optical symmetry plane $\alpha_4'\beta_4'$ is brought by the (O-V) axis to the rotating axis. This proves that the nearest principal optical axis is gradually moving away from, while the farther one is approaching nearer and nearer to the center of the projection. If the procedure is continued, β could be brought to the vertical position, but in practice the farthest one cannot be commonly brought to the vertical on the universal stage, and too great an inclination should always be avoided by the operator.

In order to simplify the processes, an approximate determination of the position of the nearest principal optical axis is necessary. After the first optical symmetry plane is found, it is rotated on the microscopic stage (M) 45° from the nicols, and about the (E-W) axis. The change of the interference colors gives a rough indication of the position of the two principal optical axes. If the first optical symmetry plane is $\alpha\beta$, the position of the lowest interference color is seen, as α is vertical, and of the highest interference color, as β is vertical, because the birefringence changes from $(\gamma-\beta)$ to $(\gamma-\alpha)$; if it is the axial plane, one of the optic axes can always be seen, and the interference color will increase from darkness to the highest color and then again decrease, for the birefringence changes on

either side of the optic axis from 0 to $(\gamma-\beta)$ or $(\beta-\alpha)$. If two optic axes are seen, the bisector determines the position of the principal optical axis. Instead of watching for the highest or lowest interference colors, the Berek compensator may be introduced, and a maximum or minimum compensation is easily measured on the graduated drum. When the nearest principal optical axis is approximately determined, the direction of rotation about the (I-V) axis, whether clockwise or counter-clockwise, and the approximate amount of rotation may be determined by the stereographic net, as shown in Fig. 1. α is the axis, and P the normal of the section. The great circular arc AB is the angle in the counter-clockwise direction.

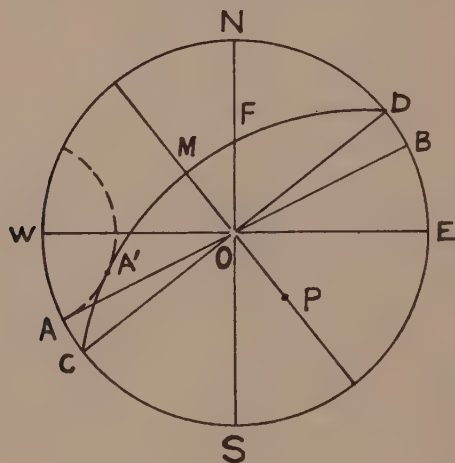


FIG. 2

In determining the composition of the feldspar, any crystallographic constant, such as composition face, cleavage plane or crystal face, should be measured after the position of orientation is obtained. It is convenient to measure the inclination of a cleavage plane or composition face on the (E-W) axis, and the direction of the vertical position from the east-west wire on the (O-V) axis, as pointed out by Emmons. Because the (O-V) axis is dependent on the (E-W) axis, and both movements will interfere with each other, the writer measures on the microscopic stage (M) the direction of the cleavage or composition face from the east-west wire when it is tilted to the vertical by the (E-W) axis, without disturbing the position of orientation. In table I, it may be seen that the compositions

Rock: *Gabbro*.

LOCALITY: Choyang, Jehol, China.

MINERAL: Labradorite, $N_m = 1.56$

HEMISPHERE: N = 1.554

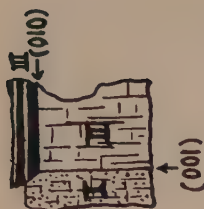
ZERO POSITION: (M) = 0.4° ; (O-V) = 270° 

TABLE I

	(I-V)	(N-S)	(O-V)	(E-W)	(M)	Composition	Remarks
I Position of orientation, $\alpha \perp$; $\beta \parallel E$; $\gamma \parallel N$. (001), the composition face of I-II (010)	348.4°	38° E	293.2°	0°	0.4°	57% An	
	—	—	—	37.7° S	316.1°	56% An	
	—	—	—	16.5° N	27.7°		
II Position of orientation, $\alpha \perp$; $\beta \parallel E$; $\gamma \parallel N$. (001), the composition face of I-II (001), the composition face of I-II* (010), the composition face of II-III (010), the composition face of II-III*	40.5°	18° E	310°	0°	0.4°	56% An	2E = $105^\circ \pm$ about α
	—	—	—	37.5° N	46.4°	56% An	
	—	—	2.2°	23° N	—	56% An	
	—	—	—	14.5° S	331.7°	56% An	
	—	—	278.5°	12° S	—	54% An	
III Position of orientation, $\alpha \perp$; $\beta \parallel E$; $\gamma \parallel N$. (010), the composition face of II-III (010), the composition face of II-III* (001) (001)*	22°	20° E	320°	0°	0.4°	51% An	2E = $105^\circ \pm$ about α Lamellae too narrow
	—	—	—	11.5° S	334.2°	?	
	—	—	292.5°	5° S	—	55% An	
	—	—	—	37.2° N	49°	54% An	
	—	—	15.2°	21.5° N	—		

* Angles measured on the (O-V) and (E-W) axes.

of the twinning members II and III determined by the angles measured on the (O-V) and (E-W) axes are occasionally uncertain. In the present procedure, the vertical angle is measured on the (E-W) axis, and the direction measured on the microscopic stage (M). They are not the true dip and strike of the cleavage on the position of orientation, but they may be obtained indirectly by the stereographic projection as shown by Fig. 2. AB is the direction of the cleavage plane when tilted to the vertical, and OF, the vertical angle measured on the (E-W) axis southward. If the section returns to the original position of orientation, A will fall on A' on the small circle, and O on F. The great circle CA'FD is the trace, CD the strike, and OM the true dip of the cleavage plane, whose pole is at P. Transfer the stereographic projection on the corresponding feldspar orientation chart, and its composition is determined as usual.

DETERMINATION OF TWINNING

The method of locating the twinning axis is the same in principle as that proposed by Emmons on his modified universal stage. Here an additional procedure should be made before changing the optical and crystallographical constants of the twinned members to the cardinal position of the unit one which is chosen as reference, because the (N-S) axis does not remain in the same direction for the different measurements. It is better to explain the procedure by means of the following example.

The poles of the cleavage planes as well as the composition faces of the three members are plotted first on the position of orientation, as shown by Fig. 3. N_1S_1 is the direction of the (N-S) axis of member I, 23.2° clockwise from the NS line; N_2S_2 is the direction of the (N-S) axis of member II, 40° clockwise from the NS line; and N_3S_3 is the direction of the (N-S) axis of member III, 50° clockwise from the NS line. Member II is chosen as reference for the determination of twinning. Rotate all the optical and the crystallographical constants to the plane of the section, so that the constants of member I are inclined 38° E³ about the N_1S_1 line, those of member II inclined 18° E about the N_2S_2 line, and those of member III inclined 20° E about the N_3S_3 line. Individual II being chosen as reference, so its constants are not rotated, for they will turn back

³ No corrections are made because the difference of the indices of the hemisphere and the mineral is very small.

to their original positions at the end of the procedure. Rotate all of I and III to the position of orientation of II by the following procedures. Because I has been rotated $52.1^\circ (= 40.5^\circ + 360^\circ - 348.4^\circ)$ counter-clockwise from II about (I-V), and $16.8^\circ (= 310^\circ - 293.2^\circ)$ counter-clockwise from II about (O-V), all the constants of I have therefore to be rotated $68.9^\circ (= 52.1^\circ + 16.8^\circ)$ clockwise from their preceding position, and then rotated 18° W about the N_2S_2 line in

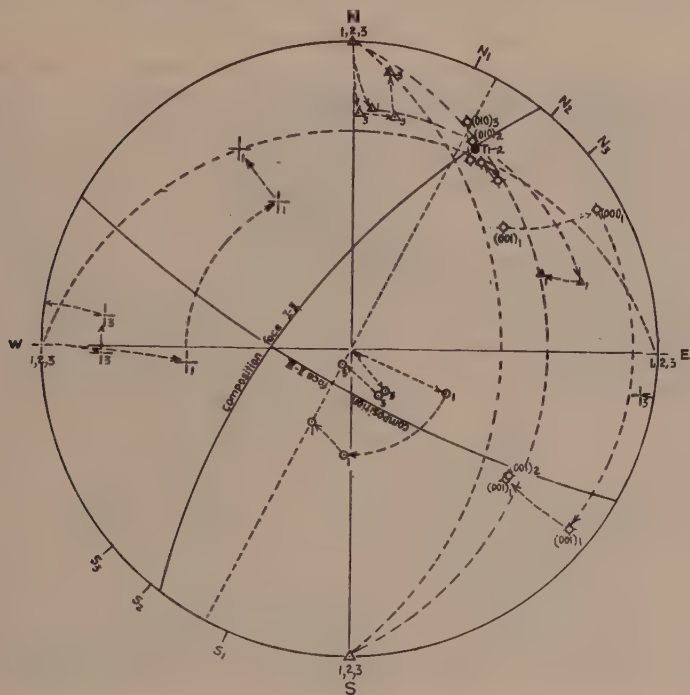


FIG. 3

order to reach the position of orientation of II; and III has been rotated $18.5^\circ (= 40.5^\circ - 22^\circ)$ counter-clockwise from II about (I-V), and $10^\circ (= 320^\circ - 310^\circ)$ clockwise from II about (O-V), so all of III must be rotated $8.5^\circ (= 18.5^\circ - 10^\circ)$ clockwise from their preceding positions, and then rotated also 18° W about the N_2S_2 line to reach the reference position. The successive movements of the principal optical axes and the poles of the cleavage planes of both I and III are shown in the figure by the arrows. The pole of $(001)_1$ nearly coincides with that of $(001)_2$, which is the pole of the com-

position face of I and II. T_{1-2} , the intersection of the three great circles joining similar optical constants, is the twinning axis of I and II. It is the Manebach-Ala A. The axis of albite twinning of II and III should fall on the pole $(010)_2$, but here no intersection is definitely located, for the twinning lamellae of III are too narrow for accurate determinations.

CORRECTION OF THE VERTICAL ANGLES

All the vertical angles should be corrected before plotting according to the method suggested by Emmons, if the difference between the indices of the glass hemisphere and the mineral is large.

ACKNOWLEDGMENTS

The writer's thanks are due to Professor E. S. Larsen and Mr. H. Berman for helpful criticism. Grateful acknowledgments should be expressed by the writer for the valuable advice and many important corrections given by Professor Larsen. Thanks are also due to Dr. Wong, the director of the Geological Survey of China, for offering the writer many facilities in these petrographical and mineralogical studies.

NOTES AND NEWS

ENARGITE AND PLUMBOJAROSITE AT PICHER, OKLAHOMA

ALFRED L. RANSOME, *Stanford University*.

For many years the presence of an interesting assemblage of minerals in the lead-zinc deposits of the Tri-State District has been known and many papers have been published concerning this locality, but not until recently has there been any mention of the



FIG. 1. Photograph of a portion of the specimen from the Barr Mine. The black crystals of enargite can be seen on the calcite crystals in the center of the picture.

presence of the mineral enargite in this region.¹ It is further believed that plumbojarosite has never been described from the district.

The basis for the following presentation is a very interesting and rather unusual specimen collected by the author from one of the numerous caves in the Barr Mine, located in the Picher District,

¹ McKnight, E. T., Occurrence of enargite and wulfenite in ore deposits of Northern Arkansas: *Econ. Geology*, vol. 30, p. 61, 1935.

Oklahoma, during one of the excursions connected with the International Geological Congress of 1933.

This specimen measuring about $8\frac{1}{2}$ by 5 by 3 inches was obtained from the roof of the cave which itself was completely covered by the minerals described in the following paragraphs. The surface originally attached to the roof of the cave, otherwise referred to as the back surface, is a typical chert breccia more heavily mineralized than usual. The few chert fragments are surrounded by sphalerite which together form the greater part of the specimen. The remaining portion consists primarily of masses of chalcopyrite crystals and calcite crystals which formed on the sphalerite, together with some gypsum, marcasite, covellite, sulphur, quartz, ruby blende (secondary sphalerite), dolomite, galena, anglesite, plumbojarosite, and enargite. The accompanying photograph (Fig. 1) gives a general view of a portion of the specimen. The scale is shown by the large banded calcite crystal which is slightly more than $1\frac{1}{2}$ inches in actual length.

Sphalerite

Forming the main mass of the specimen, the sphalerite occurs as large intergrown crystals enclosing the chert fragments (not visible in photograph). The color varies from amber through brown to reddish-brown, and the luster is characteristically adamantine. Recognizable on the sphalerite is $\{111\}$ twinning, but the crystal faces are malformed.

There is a second generation of sphalerite of a deep reddish color, known as ruby blende, present on the back surface of the specimen. The crystal size of the ruby blende is from 1–3 mm.

Chalcopyrite

Covering most of the upper surface of the specimen, the chalcopyrite occurs as masses of intergrown crystals of varying sizes up to one-fourth to three-eighths inches. In each individual mass there is a roughly parallel growth of crystals. The surface is coated with a very thin oxidation product of a brownish-yellow color.

These crystals consist of the tetragonal bisphenoid $p\{111\}$ modified by $z\{201\}$, both of which show striations, and a line face $\{100\}$. These striations are possibly the cause of a sheen on the crystal surfaces noticeable when they are turned at an angle to the light.

Calcite

One of the most interesting of all minerals in the Tri-State District is calcite which occurs in unusually large crystals. The lower part of the cave was covered with these large crystals many of which reached a size of two to three feet. The calcite crystals on the specimen are small, varying in size from one-half to two inches in length, but are exactly the same in form as the large ones, being ditrigonal scalenohedrons, $v\{21\bar{3}1\}$. The color varies from colorless to white and amber. These crystals are well shown in the photograph.

Some of the transparent crystals reveal inclusions of chalcopryrite. When viewed with a hand lens these crystals show the double refracting property of the calcite, a double image being clearly discernible.

Gypsum

The basal portion of the majority of the calcite crystals are covered with a thin coating which is very soft and easily scraped off with the fingernail. Examination under the microscope showed thin tabular and platy crystals recognized as gypsum. A chemical test as well as the determination of the index of refraction of these crystals gave further positive proof.

This mineral is replacing the calcite as shown by small pits under the coating, and it is probable that oxidation products of the sulphides reacted with the calcite to form the coating of gypsum.

The white color of the pure gypsum grades through green into a deep brown towards the base of the calcite crystals. Inspection showed that these bands are merely stains on the gypsum most likely caused by copper and iron from the chalcopryrite. The gypsum as well as the banded effect of the staining is well shown in the photograph.

Enargite

Many tests were made before this mineral was decided conclusively to be enargite (Cu_3AsS_4). The crystals are formed mainly on the calcite and are in places partially imbedded. Numerous crystals can be seen on the calcite in the center of the photograph. They are also present on the chalcopryrite. This has been noted on several specimens beside the one in question.

The enargite occurs as small rhombic crystals, averaging from 2-3 mm. in length, which are columnar in form and have a good

cleavage parallel to the length. The value for the angle $110 \wedge \bar{1}\bar{1}0$ was determined with a reflection goniometer, taking an average of twenty readings, and found to be $81^{\circ}49'$ as compared with the recorded figure of $82^{\circ}07'$.² This is the average of readings from all the *m* faces. One angle measured $82^{\circ}06'$ which is very close to the recorded value.

An open tube test was made which resulted in fumes of SO_2 , a very faint sulphur sublimate, and a white sublimate consisting of very minute crystals of As_2O_3 having an adamantine luster. A borax bead test gave a clear light blue color indicating the presence of copper.

Marcasite

A comparatively small amount of this mineral was found in a few places on the chalcopyrite. The crystals are small measuring not over four mm. in the line of greatest dimension and are tabular orthorhombic with the structure typical of marcasite. The following forms were recognized: $c\{001\}$, $m\{110\}$, and $\{0kl\}$. The color is a pale brass yellow with a dull surface tarnish.

Covellite

A very thin indigo-blue coating on the sphalerite between the clusters of chalcopyrite and occasionally on the chalcopyrite and the base of the calcite is thought to be the copper mineral covellite. A test for copper was not made because of the difficulty of obtaining pure material which was not contaminated with small particles of the surrounding chalcopyrite.

Sulphur

Another product of oxidation, sulphur, occurs as a very large number of minute orthorhombic crystals on the chalcopyrite and sphalerite. Of a pale yellow-green color, these crystals are clear with an adamantine luster. They are soluble in carbon disulphide.

Quartz

A few very small prismatic crystals of secondary quartz were found on the back surface of the specimen deposited on the sphalerite. The recognizable crystal forms are: $m\{10\bar{1}0\}$, $r\{10\bar{1}1\}$, and $z\{01\bar{1}1\}$.

² Dana, E. S., *System of Mineralogy*, 6th edition, p. 147, 1904.

Dolomite

A small amount of dolomite is also present on the sphalerite near the quartz and ruby blende. The crystals are small saddle-shaped rhombohedrons, pink in color.

Galena

The large crystals of galena common in this district are not well represented on the specimen. Only a few highly oxidized nodules are present on the sphalerite. A few remnants of original faces show them to be octahedral crystals with the form $o\{111\}$, some showing the usual cubic form $a\{100\}$. There is a definite cubic cleavage.

Anglesite

The anglesite occurs as a thin gray film on the galena. Positive tests were made both for the lead and the sulphate radical.

It is possible that some cerussite is also present associated with the galena but no determination was made because of the difficulty of obtaining material upon which to make a test.

Plumbojarosite

This member of the alunite group, new to the district, was found in only two places on the specimen occurring as a brownish colored earthy material covering nodules having a center of galena.

Under the microscope a small amount of this earthy material in suspension in water showed numerous very minute platy crystals (approximately .01 mm. in diameter) which had the hexagonal shape and yellow color suggesting a member of the alunite group.

A test of an HCl solution with potassium iodide gave a positive reaction for lead producing platy hexagonal crystals with a yellow color, and of larger size than the original crystals found in the water solution. On addition of a few particles of calcite to the HCl solution and heating, microchemical gypsum was formed indicating the presence of the sulphate radical and definitely establishing the mineral as plumbojarosite.

ORDER OF SEQUENCE

It is impossible to list the above minerals in a definite order of sequence that will show the relation of each mineral to the other. However, it is evident that the sphalerite was succeeded by the calcite, chalcopyrite, and dolomite which were formed at approxi-

mately the same time. The enargite as far as can be determined followed soon after.

Galena and marcasite probably were formed next but in what order is not known. Covellite was precipitated after the chalcopyrite, following which the sulphur was formed. The gypsum replaced the calcite, and the lead minerals developed from the galena.

The quartz was deposited on the sphalerite followed by the ruby blende. Whether these two were formed early or late in the sequence is not easily determined and any statement one way or the other would be merely a guess.

DISCUSSION

The presence of such an assemblage of minerals in one specimen is quite unusual. The mineral enargite is most interesting from the standpoint of the origin of the deposits which has been a much debated question for many years.

The most recent theory to be advanced is that the deposits were formed by thermal solutions originating from a magmatic source. Newhouse, from his work with inclusions in sphalerite, has contributed data which greatly supports this theory.³ Inclusions of an aqueous solution of NaCl containing a bubble were heated until the bubble disappeared thereby giving the temperature of formation of the sphalerite. By this method Newhouse deduced that the temperature of formation of the ore minerals at Picher, Oklahoma, was from 125°–130°C.

Also in support of the magmatic theory is the recent evidence of the existence of known intrusive rocks in the vicinity of the ore deposits of the Tri-State District. This has been emphasized by Weidman as being closely related to the structure of the region as well as the ore deposits.⁴ This fact eliminates what was considered the great weakness of the magmatic theory, namely, the absence of such intrusives in the vicinity of the ores.

The occurrence of tourmaline in the jasperoid has been described by Weidman who considers it as additional evidence for the above theory.⁵ He definitely states that the small crystals are not detrital

³ Newhouse, W. H., Temperature of formation of Mississippi Valley lead zinc deposits: *Econ. Geology*, vol. 28, pp. 744–750, 1933.

⁴ Weidman, Samuel, The tri-state zinc-lead region: *16th International Congress, Guidebook 2*, pp. 74–91, 1933.

⁵ Weidman, Samuel, Tourmaline in jasperoid of the Miami-Picher zinc-lead district: *Geol. Soc. Amer.*, Preliminary list of titles and abstracts of papers to be offered, 46th ann. meeting, Dec. 1933.

or clastic, but crystallized from solutions at a temperature of from 200°–300°C.

Enargite, as compared with the tourmaline, is generally considered to be a mineral formed at an intermediate temperature, at least higher than that usually associated with deposition by meteoric waters. Such a mineral by itself might not be of much significance, but when accompanied by such evidence as stated above, the presence of enargite may also be of importance in supporting this recent theory.

ACKNOWLEDGMENT

The minerals described above were determined in the mineralogical laboratories of Stanford University with the kind assistance of Prof. A. F. Rogers and Dr. L. W. Staples.

THULITE IN NEW MEXICO

STUART A. NORTHROP, *University of New Mexico, Albuquerque, New Mexico.*

Since thulite has been reported in North America from only two localities, at Hampton, Maryland,¹ and at Haddam, Connecticut,² its occurrence in New Mexico is worthy of record. Thule is an ancient name of Norway; the mineral has been found at three localities in Norway, at one locality in Austria, and at one in Italy. There are probably few American mineralogists who have seen thulite in the field.

The new locality is just south of Pilar Post Office (village formerly known as Cieneguilla), Taos County, New Mexico, approximately in the N.E. $\frac{1}{4}$ Sec. 2, T. 23 N., R. 11 E., on the east bank of the Rio Grande. From Pilar the Rio Grande flows southwestward for about six miles and has cut down through pre-Cambrian metamorphics, leaving a steep cliff facing northwestward. The main highway between Santa Fe and Taos lies at the foot of the cliff along the east bank of the river. The locality is northwest of the Copper Hill or Picuris mining district and northeast of the Glenwoody district.

According to Graton,³ the pre-Cambrian rocks of the region in-

¹ Lee, John W., *Am. Jour. Sci.*, vol. 11, pp. 171–172, 1901.

² Foye, Wilbur G., *Am. Mineral.*, vol 11, pp. 210–213, 1926.

³ Graton, L. C., *The Ore Deposits of New Mexico: U. S. Geol. Survey, Prof. Paper 68*, pp. 89–91, 1910.

clude granite and granitic gneiss, basic intrusives, and a variety of metamorphic rocks such as quartzites and knotty schists containing quartz, sericite, biotite, tourmaline, garnet, corundum, sillimanite, andalusite, cyanite, staurolite, magnetite, epidote, etc. Numerous pegmatite dikes, varying in width from a few inches to more than one hundred feet, have intruded the pre-Cambrian complex. About three miles to the southeast of the thulite locality is the Harding lepidolite mine, described by Schaller in 1926.⁴ On a recent hurried trip to the Harding mine the following minerals were obtained: lepidolite, purple muscovite, albite, microcline, apatite, spodumene, tantalite, green and yellow garnets, beryl, andalusite, and microlite.

At the northeastern end of the cliff of pre-Cambrian rocks just south of Pilar there are numerous prospect drifts and pits. It is at one of these hillside drifts in a large pegmatite that the thulite was discovered. The mineral occurs at the floor level of the drift but the exact geologic relations could not be determined. However, it can be stated definitely that the largest masses occur in a quartz vein, varying in width from a fraction of an inch to about two inches, which traverses a mica schist. The vein is undoubtedly related to the pegmatite. In places the thulite has penetrated and apparently replaced the schist.

The mineral has an attractive color which has been described usually as peach-blossom pink; a polished specimen from Norway is illustrated in color by Farrington.⁵ The New Mexico material is somewhat darker and richer, between rose-red and geranium-pink. The one perfect cleavage is well-exhibited; the luster is vitreous; the mineral is brittle; thin slivers are subtranslucent. For a distance of one to two inches from the vein contact the white schist contains an abundance of acicular, deeply striated prisms of thulite, up to 3 mm., and rarely 5 mm., in length. Dana gives 3.124 as the specific gravity. For the Haddam material Foye obtained 3.19.⁶ An average of five determinations of the New Mexico material, with fragments ranging up to 10×10×16 mm., gives 3.15. In addition to quartz the only conspicuous mineral associated with the thulite is actinolite, and this is rare. Because of extensive jointing and

⁴ Schaller, W. T., and Henderson, E. P., Purple muscovite from New Mexico: *Am. Mineral.*, vol. 11, pp. 5-16, 1926.

⁵ Farrington, O. C., *Gems and Gem Minerals*, p. 195, 1903.

⁶ Foye, Wilbur G., *loc. cit.*

faulting of the schist and vein it was difficult to obtain specimens larger than two inches across. Many of the joint surfaces are coated with psilomelane dendrites, some of which exhibit slickensides. Unfortunately there does not seem to be much more of the mineral available. Possibly by blasting some could be obtained.

The following analysis of the New Mexico material was made by S. B. Lippincott of the Chemistry Department of the University of New Mexico. The only other analysis of thulite found by the writer is that of material from Tellemark, Norway (quoted by Dana, page 514, 6th edition, *System of Mineralogy*).

	Norway	New Mexico
SiO ₂	42.81	49.19
Al ₂ O ₃	31.14	24.26
Fe ₂ O ₃	2.29	3.38
CaO	18.73	19.90
MgO	1.63	none
Na ₂ O	1.89	none
MnO ₂	not given	1.62
H ₂ O	0.64	1.39
Total	99.13	99.74

The higher percentage of silica in the New Mexico material is due partly to the fact that it was impossible to obtain fragments of thulite entirely free of vein quartz. In this respect the analysis is rather unsatisfactory.

The writer gratefully acknowledges the assistance of Professor William E. Ford in the determination of the mineral.

QUARTZ PARAMORPHS AFTER TRIDYMITITE AND CRISTOBALITE*

ROBERT S. MOEHLMAN, *Harvard University.*

In the course of microscopic examination of some Miocene volcanic rocks southwest of Ouray, Colorado, abnormal forms of quartz were observed which are believed to be the result of inversion from tridymite and cristobalite. The paramorphic quartz occurs in the Burns quartz latite and associated rocks, two miles west of Red Mountain.

FIG. 1. Magnification 85 \times .

Vesicles are rare in the Burns flow, but gas cavities present in one locality contain microscopic plates of quartz (Figure 1); interstitial to the quartz plates is an aggregate of fine sericite. That the plates were not an original, abnormal crystallization of quartz is shown by the discordance of the plates with respect to the present crystal orientation. A single plate may be made up of two or three quartz individuals, and conversely, one quartz individual may form two plates at an angle to each other. It is thus apparent that the quartz is pseudomorphic after some pre-existing platy mineral

* Taken from a thesis submitted in partial fulfillment of the requirements for a Ph.D. degree at Harvard University.

whose form it has inherited. The platy mineral is believed to be tridymite, one of the polymorphous forms of silica, which characteristically occurs in such plates in the vesicles of lavas. Similar structures of quartz have been described by Geijer and attributed to inversion from tridymite.¹

Another abnormal form of quartz was observed in the vesicles of a highly altered amygdaloidal lava associated with the massive quartz latite of the Burns formation. Rosette-growths of quartz

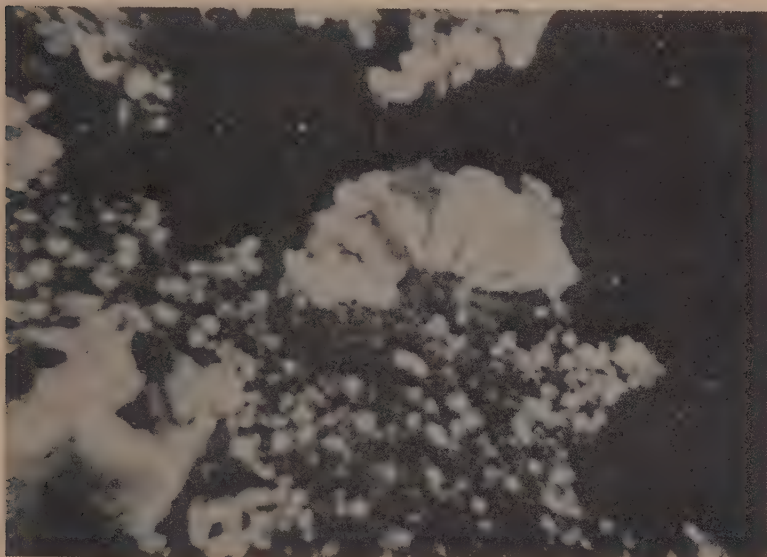


FIG. 2. Crossed Nicols. Magnification 60X.

perched on the walls of vesicles are believed to be the result of inversion from cristobalite (Figure 2). Bascom has pictured a similar growth of quartz in altered pre-Cambrian (?) rhyolite, which Idings attributed to inversion from a higher temperature form of quartz.²

Both tridymite and cristobalite are metastable forms of silica at ordinary temperatures, but in most cases inversion to the stable

¹ Geijer, Per, On Poikilitic Intergrowths of Quartz and Alkali Feldspar in Volcanic Rocks: *Geologiska Föreningens I, Stockholm Förhandlingar*, Bd. 34, Häft I, pp. 70-73, 1913.

² Bascom, F., *U. S. Geol. Survey, Bull. 136*, The Ancient Volcanic Rocks of South Mountain, Pa., Plate 27, 1896.

form, quartz, is indefinitely postponed. The transformation of tridymite or cristobalite to quartz has never been accomplished in the dry state in the laboratory. The inversion from tridymite has been performed in a water solution of sodium carbonate or by use of a sodium tungstate flux; the inversion from cristobalite in a water solution of sodium carbonate.³ In the area here described, it was doubtless the presence of alkaline waters carrying silica which facilitated inversion. Both rocks in which the paramorphic quartz is found are considerably altered, silicified and sericitized.

Although the stability ranges of tridymite and cristobalite as determined in the laboratory are 870–1470°C. and 1470–1710°C., respectively, it must be emphasized that their formation does not necessitate such high temperatures. In the words of Larsen, "The presence of tridymite or cristobalite in a rock gives no indication of the temperature of crystallization as these forms can, and commonly do, form below 870°."⁴

³ Sosman, R. B., Properties of Silica, Chemical Catalog Co., New York, pp. 76–77, 1927.

⁴ Larsen, E. S., The Temperature of Magmas: *Am. Mineral.*, vol. 14, p. 87, 1929.

PROCEEDINGS OF SOCIETIES

PHILADELPHIA MINERALOGICAL SOCIETY

Academy of Natural Sciences of Philadelphia, June 6, 1935

Dr. Joseph L. Gillson presided at a stated meeting of the society, 41 members and 35 visitors being present.

Mr. Arndt reported the results of the Rocks and Minerals Association National Outing of the Philadelphia district, held Sunday, May 19th, to Vanartsdalen's quarry, Perkiomenville, and Phoenixville.

Dr. Gillson described the Fifth Annual Field Conference of Pennsylvania Geologists, held on May 31, June 1st and 2nd, with headquarters at the Academy of Natural Sciences. Nearly 100 persons were registered as participating in the excursions described in a 43-page guide book.

Other excursions described, and specimens obtained were: by Louis Moyd to Howellville, Bridgeport (malachite), and the Perkiomen mine (ankerite); Albert Ackoff to Mauch Chunk (carnotite); Alexander Fleming, Jr., to Blue Ball (chalcopyrite, quartz, calcite), Beartown (caxoxenite); Leonard A. Morgan to Bedford, N.Y. (stibnite, beryl, smoky quartz) and Prospect Park, N.J. (chabazite and natrolite).

Mr. Henry E. Millson demonstrated a few of the new micro-chemical methods of mineral analysis developed by Dr. J. Adam Watson of Edinburgh University and

described in the *Mineralogical Magazine* (London, March 1935). Dr. William S. Newcomet exhibited an apparatus, an adaptation of the Geiger tube, which gave visible (by use of a neon tube) and audible (through a loud speaker) evidence of radium emanations.

W. H. FLACK, *Secretary*

MINERALOGICAL SOCIETY OF GREAT BRITAIN AND IRELAND

MINERALOGICAL SOCIETY, *June 6*, The President, SIR THOMAS H. HOLLAND in the chair. DR. L. J. SPENCER opened a discussion on Mineralogical Nomenclature. The following papers were read:

PROF. C. E. TILLEY: *Metasomatism associated with the greenstone-hornfelses of Kenidjack and Botallack, Cornwall*. Within the contact-zone of the Land's End granite greenstone-hornfelses can be traced through intervening stages of cumingtonite-plagioclase, and anthophyllite-cordierite assemblages to a common end-product of biotite-cordierite-hornfelses simulating sedimentary hornfelses. The metasomatism effected has been a consistent removal of lime partly compensated by additions of silica, iron oxides, and alkalis, more particularly potash.

MR. J. D. BERNAL and MR. F. A. BANNISTER: *The chemical composition and crystal-structure of ettringite*. An optical, chemical and x-ray study of ettringite from Scawt Hill, Co. Antrim. The hexagonal unit cell containing $\text{Ca}_{12}\text{Al}_4(\text{OH})_{24}\text{S}_6\text{O}_{21} \cdot 52\text{H}_2\text{O}$ has the dimensions $a = 11.24$, $c = 21.45\text{\AA}$, and the symmetry of the space-group $D_{4h}^{26} = C6/\text{mmc}$. The crystal-structure possesses channels parallel to the c -axis within which are located 48 water molecules, zeolitic in type. On heating to 110°C . this structure partially collapses leaving an oriented pseudomorph of cell dimensions $a = 8.45$, $c = 10.2\text{\AA}$ and the same space-group.

The Rev. A. F. SMETHURST: *Anomalies in the analytical determination of water in epidote*. Analyses of two epidotes from the Malvern Hills (Herefordshire) gave for "total water" only 0.06% and 0.35%, and totals of only 98.46 and 98.52 for all constituents. Epidote separated from these rocks gave similar results. The mineral has the composition and structure of normal pistacite. Examination of three specimens of typical epidote from other localities revealed similar abnormal retentiveness of combined water and a study of recorded analyses of epidote shows that in about 10% of them the behaviour of the combined water is anomalous. The cause of these anomalies is discussed.

MR. N. F. M. HENRY: *Some data on the iron-rich hypersthènes*. New chemical and optical data are given for three iron-rich hypersthènes. One of these from Mansjö, Sweden, contains 84% FeSiO_3 . Refractive index and 2V curves are extended for the MgSiO_3 - FeSiO_3 series, and a new name is proposed for the pure iron silicate end-number.

PROPOSED AMENDMENTS TO THE CONSTITUTION AND CHANGES
IN THE BY-LAWS OF THE MINERALOGICAL SOCIETY
OF AMERICA*

The Council of the Mineralogical Society of America has approved the following amendments to the Constitution of the Society and changes in the By-laws, which are to be submitted to the fellows and members of the Society for ballot by mail:

PROPOSED AMENDMENTS TO THE CONSTITUTION^a

Article II—Object

The object of this Society shall be the advancement of mineralogy, crystallography, *petrography* and allied sciences.

Article IV—Membership

Section 2. Fellows shall be persons who have published results of research on mineralogy, crystallography, *petrography* or allied sciences, and who upon nomination by the Council shall have been duly elected to fellowship in the Society.

Section 4. Patrons shall be persons who have bestowed important favors upon the Society. Election to patronship carries with it the rights and privileges of *fellows*.

PROPOSED CHANGES IN THE BY-LAWS^b

Article I—Membership

Section 1. . . . Any person or corporation interested in mineralogy, crystallography, *petrography* or allied sciences, shall be eligible to membership.

Section 2. Election. (a) Fellows. . . .

(b) Members. *Candidates for membership in the Mineralogical Society of America should be endorsed by at least one fellow of the Society and the application approved by either the secretary or treasurer acting for the Council.*

Article II—Dues

Section 1. . . . *The annual dues for fellows of the Mineralogical Society of America who also pay dues as fellows of the Geological Society of America shall be two dollars (\$2.00) payable at or before the annual meeting in advance. This provision shall continue in effect as long as the Geological Society of America shall contribute funds which the Council of the Mineralogical Society of America shall consider adequate to assist in publication of the Journal of the Mineralogical Society of America.*

Article V—Publications

The Society shall publish a journal devoted to the advancement of mineralogy, crystallography, *petrography* and allied sciences.

PAUL F. KERR,
Secretary

* See *American Mineralogist*, Vol. 11, No. 3, 1926, pp. 69–71.

^a Changes indicated in italics are to be voted upon by fellows.

^b Proposed changes in the By-laws indicated in italics are to be voted upon by ballot of the general membership of the Society.

NEW MINERAL NAMES

Mindigite

DE LEENHEER, L.: Over mindigiet, een nieuw kobalhydroxyde. *Natuurwetenschappelijk Tijdschrift*, Gent, vol. 16, pp. 237-241, 1934, *Min. Abs.*, vol. 6, No. 2, p. 52, 1935.

NAME: From locality Mindigi, Katanga.

CHEMICAL PROPERTIES: A hydrous cobalt hydroxide. $9\text{Co}_2\text{O}_3 \cdot 2\text{CuO} \cdot 16\text{H}_2\text{O}$. Analysis: Co_2O_3 76.05, 77.05; CuO 9.22, 7.34; H_2O 14.79, 14.74; insol. 0.66; total 100.06, 99.79. Heated yields water and finally some oxygen. Fuses to dark blue mass.

PHYSICAL PROPERTIES: Color pitch black, streak brownish black. Fracture conchoidal. Colloidal. Hd. $2\frac{1}{2}$. G. 3.07.

OCCURRENCE: Found as crusts with shining surface on hematite at Mindigi, 58 kms. W.S.W. of Kambove, Katanga.

W. F. H.

 α -Uranopilite

NOVÁČEK, R.: Study of some secondary uranium minerals. *Věstniku Královské České Společnosti Nauk*, vol. 2, pp. 15-16, 1935. (In English.) A lower hydrate of uranopile, $6\text{UO}_3 \cdot \text{SO}_3 \cdot 10\text{H}_2\text{O}$ is tentatively called α -uranopilite. It differs from uranopile in color (grayish, dirty green), less perceptible pleochroism, parallel extinction, higher birefringence, and higher indices ($\alpha=1.72$, $\beta=1.76$, $\gamma=1.76$). Elongation parallel with the optic normal β ; the obtuse bisectrix γ lies in the flat face (010).

 α -Uranotile

NOVÁČEK, R.: *Ibid.*, p. 24. A mineral chemically similar to uranotile (uranophane), $\text{CaO} \cdot 2\text{UO}_3 \cdot 2\text{SiO}_2 \cdot 6\text{H}_2\text{O}$, is tentatively called α -uranotile. In yellow to yellow green crystals, usually twinned. It differs from uranotile in optical properties. Biaxial. $2E$ about 130° . Strong crossed dispersion, $r > v$. $\alpha=1.665$, $\beta=1.686$, $\gamma=1.696$. Extinction $c:\gamma=41^\circ$, $c:\beta=49^\circ$, α is normal to (010). Pleochroism strong; α =nearly colorless, β and γ =deep yellow. Sp. Gr.=3.953. From Jáchymov, Czechoslovakia on uraninite.

W. F. F.

Bismoclite

MOUNTAIN, EDGAR D.: Two New Bismuth Minerals from South Africa. *Mineralog. Mag.*, vol. 24, No. 149, pp. 59-62, 1935.

NAME: In reference to its composition, a bismuth oxychloride.

CHEMICAL PROPERTIES: A bismuth oxychloride, BiOCl . Analysis: Bi_2O_3 88.49; Fe_2O_3 0.12; PbO trace; Cl 13.00; $\text{H}_2\text{O}+$ (above $110^\circ\text{C}.$) 0.45; $\text{H}_2\text{O}-$ (below $110^\circ\text{C}.$) 0.42; insol. 0.77; less $\text{O}=\text{Cl}$ 2.93; total 100.32. Gently heated in closed tube gives small quantity of acid water. Upon further heating the mineral becomes almost white, then yellow, yielding a white cloudy sublimate. At higher temperature the color darkens to orange and the sublimate collects into lemon yellow globules. Finally, the mineral melts and solidifies to a lemon yellow mass. In open tube the behavior is the same except sublimate is dense white and does not collect into

globules. In the flame gives an indistinct pale blue color. Soluble in acids without effervescence but is precipitated on considerable dilution.

PHYSICAL PROPERTIES: Color creamy white, slightly yellowish in patches. Columnar or platy-fibrous. Cleavage well defined. Luster greasy or silky, except on cleavage, pearly. Hd. = $2\frac{1}{2}$. G. = 7.36.

OCCURRENCE: Found 13 miles N.W. of Jackals Water, Namaqualand, on pegmatite outcrop, associated with muscovite.

Examination by x -rays suggests its identity with artificial, tetragonal BiOCl.
W. F. F.

Bokspütite

MOUNTAIN, EDGAR D.: *Ibid.* pp. 62-64.

NAME: From the locality, the farm Bokspüt, Cape Province.

CHEMICAL PROPERTIES: A lead bismuth carbonate, $6\text{PbO} \cdot \text{Bi}_2\text{O}_3 \cdot 3\text{CO}_2$. Analysis: PbO 67.22; Bi_2O_3 22.92; CO_2 6.96; Cl 0.99; $\text{H}_2\text{O} + 0.73$; $\text{H}_2\text{O} - 0.19$; insol. 0.34; less O = Cl 0.22; Sum 99.13.

When heated gently in closed tube it decrepitates slightly and gives off a small amount of moisture. On further heating, first becomes orange, then brown and begins to melt below red heat to a black melt, cooling to yellowish brown mass. In open tube the behavior is identical. When strongly heated on charcoal it melts easily giving a yellow sublimate near the assay, white farther away and yields soft, malleable bead. With potassium iodide and sulfur it gives an orange and red sublimate. Soluble in hydrochloric and nitric acids with effervescence. With sulfuric acid it gives a test for lead.

PHYSICAL PROPERTIES: Color yellow. Fine grained with pearly luster. Hd. = $3\frac{1}{2}$. G. = 7.29.

OCCURRENCE: Found as fine grained yellow masses in quartz veins and pegmatites with wolframite, scheelite and beryl, from Bokspüt, Langklip, Gordonias, Cape Province.

W. F. F.

Cobalto-Sphärosiderite Kobalt-Oligonspat

REISSNER, R.: Über einen kobalthaltigen Oligonspat. *Centr. Min.*, Abt. A, No. 6, pp. 170-173, 1935. A bright peach colored carbonate associated with siderite in quartz from an unknown locality gave: FeCO_3 40.48, MnCO_3 19.11, MgCO_3 21.06, CoCO_3 14.44, CaCO_3 4.34, ZnCO_3 0.61. For this mineral the name cobaltosphärosiderite or kobalt-oligonspat is proposed.

W. F. F.